Copy No. 4

~~CONFIDENTIAL~~ RM No. L6I13

Inactive

NACA

# RESEARCH MEMORANDUM

## ABSTRACTS PERTAINING TO SEAPLANES

By

Jerold M. Bidwell and Douglas A. King

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

CLASSIFICATION CANCELLED

Authority ______ Date ______

By ______ See ______

CLASSIFIED DOCUMENT

This document contains classified information affecting the National Defense of the United States within the meaning of the Espionage Act, USC 50:31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law. Information so classified may be imparted only to persons in the military and naval services of the United States, appropriate civilian officers and employees of the Federal Government who have a legitimate interest therein, and to United States citizens of known loyalty and discretion who of necessity must be informed thereof.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
WASHINGTON
July 24, 1947

~~CONFIDENTIAL~~

N A C A LIBRARY
LANGLEY MEMORIAL AERONAUTICAL LABORATORY
Langley Field, Va.

NASA Technical Library
3 1176 01436 2744

TABLE OF CONTENTS



[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

# ABSTRACTS PERTAINING TO SEAPLANES

By Jerold M. Bidwell and Douglas A. King

## SUMMARY

About 400 references pertaining to the hydrodynamic design of seaplanes have been compiled, and the information is presented in the form of abstracts classified under six main headings: GENERAL INFORMATION, HYDROSTATICS, HYDRODYNAMICS, AERODYNAMICS, OPERATION, and RESEARCH.

An author index and a subject index are included.

## INTRODUCTION

A large volume of technical information pertaining to seaplanes has accumulated but exists, throughout the world, in scattered and fragmentary treatises. Part of the large number of references pertaining directly to the hydrodynamics of seaplanes, as well as indirectly to hydrodynamic design, has been compiled and classified by the National Advisory Committee for Aeronautics. Each paper has been reviewed and abstracted with special attention given to organizing the information in such a way as to be useful to persons engaged in seaplane research and development.

The abstracts are not intended as substitutes for the original papers but serve only as condensations of the important points. It is believed, however, that in many cases the abstracts will contain sufficient information to obviate procurement of the original papers.

References used have been principally books, society journals, periodicals, American and British published and unpublished reports, and reports made available by Boeing Aircraft Company, Consolidated Vultee Aircraft Corporation, The Glenn L. Martin Company, and Stevens Institute of Technology. Miscellaneous American, British, French, German, Russian, and Spanish books and papers have also been included.

Many abstracts were taken directly from summaries in the original papers. Abstracts were also taken from "Science Abstracts" and indexes in the "Aeronautical Engineering Review." Acknowledgment is made to James M. Benson, Calvin M. Class, Ralph W. Krone, and Annie Mary Matthews for assisting the authors in the preparation of the remaining abstracts.

## METHOD OF PRESENTATION

### Abstracts

The classification system for the abstracts has been made so general as to include any conceivable report that would pertain to the hydrodynamics of seaplanes. The headings have been arranged to permit the use of a number classification system, if it is so desired at a later date.

The main headings have been designated GENERAL INFORMATION, HYDROSTATICS, HYDRODYNAMICS, AERODYNAMICS, OPERATION, and RESEARCH. The GENERAL INFORMATION classification is concerned with bibliographical references and references in which the performance or geometrical characteristics of seaplanes are described or discussed in a very general way. References that deal with a seaplane at rest in the water are classified under HYDROSTATICS. HYDRODYNAMICS, which is the main subject under consideration, contains references that relate to the hydrodynamic characteristics of a seaplane from rest to get-away. AERODYNAMICS includes information on the aerodynamic characteristics that directly or indirectly influence the design of the hydrodynamic surfaces. OPERATION contains those references in which the conditions under which seaplanes must operate are described. References which relate to the manner in which research is carried out and to the equipment used are classified under RESEARCH.

The complete classification used is as follows:

GENERAL INFORMATION

General
Design
Descriptions
Take-off
Bibliographies

HYDROSTATICS

- General
- Buoyancy
- Stability

HYDRODYNAMICS

- General
- Hydrodynamic sustentation
  - Planing surface
    - Steady condition
    - Unsteady condition
  - Hydrofoil
- Forces and moments on hulls and floats
  - Longitudinal forces and moments
    - Steady condition
      - Resistance
      - Lift
      - Moment
    - Unsteady condition
      - Resistance
      - Lift
      - Moment
  - Lateral forces and moments
    - Steady condition
      - Side force
      - Heeling moment
      - Yawing moment
    - Unsteady condition
      - Side force
      - Heeling moment
      - Yawing moment
  - Pressure distributions
- Spray and wake
- Stability under way
  - Longitudinal stability
    - Low-angle stability
    - High-angle stability
    - Stability characteristics
  - Lateral stability
    - Heel stability
    - Directional stability

AERODYNAMICS

General
Propulsive arrangements
Forces and moments on hulls and floats

OPERATION

General
Piloting
Seaplane bases
Seaways

RESEARCH

General
Equipment
Technique

The abstracts are arranged alphabetically by title under the headings and are numbered consecutively. At the end of each group of abstracts, reference is made to other abstracts which contain, in part, information of interest on the same subject. In cases in which two or more reports contain similar analyses of the same data, the abstracts are grouped together under the same abstract number with successive abstracts taking letter suffixes. The most complete or the most generally available report is listed first.

Abstractors' notes are enclosed by brackets.

## Author Index

In hydrodynamics, as in other fields of research, the names of the authors are very useful in locating information of a type for which an author is well known. The names of the authors of the papers given are indexed alphabetically. After the name of each author, a list of abstract numbers is given indicating the reports of which he was author or coauthor.

## Subject Index

The subject index is intended to meet the needs of persons interested in the specific details of the hydrodynamics of seaplanes. Research and design parameters, auxiliary devices, specific functional parameters, and seaplane designations are listed. The subject index is not intended to be complete but includes the factors that appear to be of most interest to seaplane specialists.

ABSTRACTS

# ABSTRACTS

GENERAL INFORMATION
General

1. Burgess, C. P.: Aeronautics in Naval Architecture. SAE Jour., vol. 40, no. 1, Jan. 1937, pp. 13-18.

Naval architecture and aeronautics are compared to show what each has learned from the other. Design and performance of airplanes, flying boats, airships, hydroplanes, steamships, and sailboats are given with the advantages and disadvantages of each type. The outstanding performance record of the Graf Zeppelin is cited as proof that the airship is more suitable than the airplane for long-range oceanic transport. Submerged hydrovanes for hydroplanes, seaplanes, and flying boats, with their advantages and disadvantages, are discussed. An aeronautical method of analysis is used to explain why some yachts are closer-winded than others with similar sails and rigging.

2. Schildhauer, C. H.: A Ballot for the Flying Boat. Aviation, vol. 43, no. 5, May 1944, pp. 119-121, 263, 267.

After the war, when low operating costs will be a primary requisite, the flying boat will hold a prominent place in international air transport. Comparisons of the speed, fuel-cargo ratios, ton-mile figures, terminal costs, maintenance, and other factors show that for 175,000-pound airplanes at a representative range of 3000 miles the operating cost of the landplanes will be 62 percent more per ton-mile than that of the flying boat.

3. Roché, J. A., and Pack, M. N.: Bombers (Second Edition). Appendix A by Ralph L. Cram, Boeing Aircraft Co.; appendix B by A. A. Priester, Pan American Airways. ACTR No. 4401, Materiel Div., Army Air Corps, July 29, 1938.

Appendix A: A Discussion of Some of the Relative Merits of Landplanes in Comparison to Seaplanes.

A comparison was made of the relative merits of a landplane and a seaplane having a gross weight of 41,000 pounds and similar wing and power loadings. It was found that the seaplane is heavier due to the large hull and the reinforcements of the aerodynamic structure necessitated by hydrodynamic factors. The high air drag of the hull seriously handicaps the performance of the seaplane. Landplanes are limited in gross load largely by the length of the runways while

GENERAL INFORMATION
General

seaplanes are limited by insufficient thrust for take-off. Seaplanes are particularly unsuitable for the installation of pressurized cabins and for strategic bombing combat.

Appendix B: Landplanes vs. Flying Boats.

Evidence is given which shows that seaplanes are more expensive and heavier than landplanes but that their real disadvantage lies in the low cruising speed of present designs. As seaplanes get larger, the disadvantages will become fewer. A program of future design is briefly reviewed. The critical relation between comfort of the operating crew and efficiency of operation is discussed. A reevaluation of the weights of landplanes and seaplanes reveals that the seaplane is more efficient than the landplane.

4. Parkinson, John B., and Fisher, Hazel S.: The Performance of Long-Range Transport Airplanes Powered by Four 3000-Horsepower Engines. NACA MR No. L5E29, Bur. Aero., 1945.

Charts are presented showing the performance of long-range transport landplanes and seaplanes powered by four 3000-horsepower engines and operating at 10,000 feet altitude over a range of 3500 miles. The performance characteristics considered are average cruising speed at 60-percent power at 10,000 feet, pay load, and ton-miles per hour per horsepower as functions of the wing loading and power loading (gross weight). The charts indicate the dependence of the performance requirements of interest in long-range transport operation on the primary performance parameters and enable an evaluation of the effects of differences in drag to be made at comparable values of these parameters. It is concluded that reduction of the large body drag of the seaplane as compared with the landplane constitutes the most promising means for improving its long-range transport effectiveness.

5. Alfaro, Heraclio: Possibilities of Large Flying Boats for National Defense. Aero Digest, vol. 37, no. 4, Oct. 1940, pp. 43-45.

The present war has not definitely established whether airplanes are sufficient for coastal defense or are to be preferred to battleships, but there is a tendency toward aircraft. Characteristics of

GENERAL INFORMATION
General

a large flying boat - the largest that the present state of knowledge makes it feasible to construct - are presented, and the possible use of this flying boat for military service is considered. Ninety-four flying boats of this type could be constructed for the cost of one battleship. Load-carrying capacities of both are compared, and the strategic value of flying boats in protecting the Panama Canal is pointed out.

Four new engines executed in twin form and giving 6000 to 7000 horsepower each, or a total of 28,000 horsepower, are proposed for the flying boat, with the assumption that these engines can be produced in a limited quantity 2 years from now. Other basic characteristics of the super-airplane contemplated include: power loading, 12 pounds per horsepower; wing loading, 50 pounds per square foot; aspect ratio, 9; maximum lift coefficient $C_{L_{max}}$ (with flaps), 2.5; gross weight, 336,000 pounds; wing area, 6720 square feet; span, 245 feet; and minimum flying speed, 88 miles per hour.

Disposal load, taken as 50 percent of the gross load, is divided as follows: crew, equipment, and fixtures, 8500 pounds; fuel for 20 hours at 50 percent maximum power, 112,000 pounds; guns and ammunition, 7500 pounds; bombs, 40,000 pounds; total useful load, 168,000 pounds. Space would be provided to carry 100,000 pounds of bombs with a reduced fuel cargo allowing a range of approximately 10 hours. Cruising speed of 272 miles per hour at 20,000 feet would permit a range of 5400 miles. Weight of armament equipment, performance, design features, advantages of Diesel power plant and the cost and time necessary for production are considered.

6. Courtney, Frank T.: Remote Propeller Drives. Part I. Aviation, vol. 41, no. 5, May 1942, pp. 82-85, 247.

The general problem of transmitting power from conveniently located power plants to remote propeller units is presented. Transmission by mechanical, hydraulic, and electrical methods is discussed. The seaplane is cited as an example of remote propeller drive because the propellers must be out of the water spray.

GENERAL INFORMATION
General

Courtney, Frank T.: The Future of Water-Based Airplanes. Part II. Aviation, vol. 41, no. 7, July 1942, pp. 91-93, 288, 291-292.

The general aspects of water-based aircraft are discussed and the possible advantages of the waterplane over the landplane are cited.

Courtney, Frank T.: The Future of Water-Based Airplanes. Part III. Aviation, vol. 41, no. 8, Aug. 1942, pp. 93-95, 252, 255.

The reasons for the present superior performance of landplanes are discussed. The more annoying problems of waterplanes are presented and discussed with a statement of the evolution of the form.

Courtney, Frank T.: The Future of Water-Based Airplanes. Part IV. Aviation, vol. 41, no. 9, Sept. 1942, pp. 116-119, 285-286.

Particular emphasis is given to problems relating to the form of the bottom. Dead rise and complex transverse forms are discussed from the standpoint of impacts and hydrodynamic performance.

Courtney, Frank T.: The Future of Water-Based Airplanes. Part V. Aviation, vol. 41, no. 10, Oct. 1942, pp. 122-123, 314, 317-318, 321-322.

Special attention is given to the subject of porpoising. The problem is presented and some attempt is made at analysis. Hydrofoils are introduced and a suggestion is made that they might possibly be of some use in improving the performance of waterplanes.

Courtney, Frank T.: The Future of Water-Based Airplanes. Part VI. Aviation, vol. 41, no. 11, Nov. 1942, pp. 122-123, 284-288.

The subject of the air drag of hulls is touched upon with reference to the placing of necessary excrescences. "Rough water," its meaning, and its effects upon performance are noted. Handling of waterplanes at their mooring is discussed and some ideas are presented. The series of articles are summarized and conclusions are reached.

GENERAL INFORMATION
General

7. Warner, Edward P.: Seaplanes for Commerce. NACA TM No. 193, 1923.

The United States and the British Isles are well fitted, by virtue of their geographical characteristics, for the development of seaplanes on commercial air lines. Seaplanes have three commercial advantages over landplanes: superiority of speed over existing means of transport on the same routes; availability and ease of use of emergency landing areas; and saving of time at terminals, for, in general, business districts of cities are located near the water fronts.

8. Schuettel, Frederick P.: Some Aspects of the Seaplane. Aero. Engineering, Trans. A.S.M.E., vol. 3, no. 4, Oct.-Dec. 1931, pp. 139-143.

After a brief historical résumé, marine aircraft are discussed with reference to efficiency, constructional features, design of floats and boats, engine arrangement, beam loading, seaworthiness, service questions, official requirements to be met, and so forth. Many tables, charts, and illustrations are included.

The discussion of seaworthiness is of special interest because it incorporates the behavior of the seaplane during: (1) mooring, (2) drifting, (3) towing, (4) taxying, (5) landing, and (6) taking-off and also includes a discussion of different methods of embarking and beaching.

9. Sikorsky, Igor: Trend in Design of Large Flying Boats. Aero. Digest, vol. 33, no. 5, Nov. 1938, pp. 44-47, 76, 84.

A comparison of the relative efficiencies of landplanes and seaplanes usually results in a discussion of two major factors: air drag and useful load.

The disadvantages of seaplanes in having greater air drag are compensated by the need of landplanes for elaborate landing gear. In small land aircraft the increase in weight due to landing gear is a small factor compared with the high air drag of the seaplanes, whereas in large long-range transports (200,000 lb) the weight of the landing gear becomes a deciding factor in favor of the seaplane.

GENERAL INFORMATION
General

As it is evident that the airliners of the future will be of large size, the flying boat will be more efficient than the landplanes in addition to having advantages of safety and service.

It is noted that valuable results may be obtained not only by the usual research in towing tanks but also by towing models with a specially arranged motor boat.

(See also abstract 113.)

Design

10. Boulton, B. C.: Aerodynamic Factors in the Design of Long Range Flying Boats. Jour. Aero. Sci., vol. 4, no. 6, April 1937, pp. 254-257.

The various factors involved in the equations of speed and power required at maximum lift-drag ratio and the Bréguet formula for range are considered with special reference to the effects of wing span, parasite drag, propeller efficiency, specific fuel consumption, altitude, headwinds, and gross weight on cruising speed and range. The application of the basic principles to the determination of some of the main characteristics of a flying-boat design is briefly discussed.

11. Richardson, Holden C.: Aircraft Float Design. The Ronald Press Co., 1928.

Because information on aircraft float design existed in isolated and fragmentary treatises on pertinent phases and in many cases actual references were unavailable, a real need has been indicated for a presentation and discussion of the fundamentals of aircraft float shapes and arrangements. The subject of design is treated from the viewpoint of form, arrangement, and proportion, and is carried into the determination of performance. Considerations affecting loading conditions are pointed out and the usefulness and importance of model tests are emphasized. Some attention is given to design features, tried heretofore

GENERAL INFORMATION
Design

and found unsatisfactory, and the records of some failures, where these disclose little-known or novel phenomena of importance, are included.

12. Diehl, Walter S.: The Application of Basic Data on Planing Surfaces to the Design of Flying-Boat Hulls. NACA Rep. No. 694, 1940.

Basic lift data on planing surfaces have been analyzed and the data applied to the design of flying-boat hulls. It is shown that a balance between air and water forces requires that the beam of the planing area bear a relation to the wing area which is determined by the lift coefficient of the wing and by the angle of dead rise in the planing surface. It is also shown that the fore-and-aft extent of the required planing area depends on the angle of dead rise. Failure to provide sufficient length of planing area appears to be the main reason for the poor water performance sometimes obtained when a large angle of dead rise is used.

13. Locke, Fred W. S., Jr.: A Correlation of the Dimensions, Proportions, and Loadings of Existing Seaplane Floats and Flying-Boat Hulls. NACA ARR, March 1943.

Inasmuch as the design of seaplanes and flying boats is a series of compromises, a study has been made to determine as far as possible what loadings and proportions have been arrived at by designers and what, if any, interrelations exist between the loadings and proportions. Differences among the designs considered are in part determined by varying requirements and the designs are not all of equal merit. The study has been limited generally to seaplanes built in the last decade, although a few interesting older designs have been included. Only seaplanes built in America, Britain, and Germany were used in the study. Data were obtained from American and British periodicals and official publications. In cases where figures were unavailable, values were scaled off drawings. Various plots were made and from these plots formulas of average design values have been developed.

GENERAL INFORMATION
Design

14. Rumpler, E.: Design and Development of Seaplanes for Transatlantic Service. Aero. Engineering, Trans. A.S.M.E., vol. 3, no. 4, Oct.-Dec. 1931, pp. 127-137.

The various problems involved in the design and construction of a multiengine twin-hull flying boat capable of making a transoceanic nonstop flight of 5000 miles and carrying a pay load of 21 tons are discussed. Among the topics included are location of engines and propellers, influence of load distribution on weight of wing structure, aerodynamical researches of the Göttingen laboratory on a model of an airplane designed by Rumpler, hydrodynamic tests in the tank at the Hamburg Shipbuilding Research Institute, influence of various factors on size of pay load, maximum power outputs from oversize engines at various altitudes, and necessity of greatly increased airplane speeds. A water trimming rudder is recommended for use when the air elevators are ineffective at planing speeds. English and German research activities show that the actual maximum water resistance is considerably lower than the value obtained by converting model results in accordance with Froude's law and, compared with the model results, it occurs at lower speeds. Catapulting and rocket-assisted take-offs are briefly discussed as to their use on long-range aircraft.

15. Sottorf, W.: The Design of Floats. NACA TM No. 860, 1938.

Following a summary of the multiplicity of domestic and foreign floats and a brief enumeration of the requirements of floats, the take-off process is discussed, with special reference to the effect of the afterbody.

The essential form parameters and their effect on the qualities of floats are detailed. The parameters discussed include beam, length and shape of forebody, dead rise, chine curvature, depth and location of step, and angle of afterbody keel. On this basis a standard float design is developed which in model families with varying length-beam ratio (6.04, 7.50, 9.19) and angle of dead rise (20°, 25°) is analyzed by an experimental method which permits its best utilization on any airplane. A comparison with the best U.S. NACA model no. 35 reveals the quality of the DVL standard float which, among others, is used on the Ha 139 of the German Luft Hansa.

GENERAL INFORMATION
Design

16. Gouge, A.: The Design of Seaplanes. Aircraft Engineering, vol. II, no. 18, Aug. 1930, pp. 202-206.

Some of the history of seaplanes is given briefly and the importance of seaplanes in large aircraft designs is emphasized. The problem of lateral stability is introduced and charts are presented to show the water resistance of tip-float, twin-float, and stub-wing systems of stabilization as functions of speed and trim. Particular emphasis is placed on the design of the float structure and several significant equations are presented. Pressure measurements were made by the Short Brothers on the bottom of a model flying-boat hull and a plot of the pressure distribution at a speed corresponding to 30 knots full size is given.

17. Parkinson, John B.: The Design of the Optimum Hull for a Large Long-Range Flying Boat. NACA ARR No. L4I12, 1944.

Principles for designing the optimum hull for a large long-range flying boat are proposed to suit the requirements of minimum drag, seaworthiness, and ability to take off and land at all operational gross weights. The principles include the use of moderate gross-load coefficients, ample forebody lengths, and deep steps and the close adherence of the form to that of a streamline body of revolution with a moderate fineness ratio.

The validity of the design principles is illustrated by the results of tests in Langley tank no. 1 and in the Langley two-dimensional low-turbulence pressure tunnel of the form of the hull for a 400,000-pound transport flying boat. These results indicate that for large airplanes satisfactory hydrodynamic characteristics can be attained without an undue penalty in flight performance caused by the drag of the step and the chines.

The effect of size on the proportions and the take-off performance of long-range flying boats is shown for three hypothetical flying boats having gross weights of 120,000, 300,000, and 480,000 pounds and the same wing loading, power loading, and hull loading. When these loadings are held constant, the size of the hull relative to the wing and the take-off time and distance are decreased as the gross weight is increased.

The hull of the flying boat, aside from its inherent ability to take off and land at sea, provides an immediate solution for the landing-gear problem of large long-range airplanes.

GENERAL INFORMATION
Design

18. Benoit, Lieutenant: Designing Seaplane Hulls and Floats. NACA TM No. 376, 1926.

A seaplane should have a quick take-off, be seaworthy, and have a strong, light, and simple structure. Slight modifications of the shape of the hull or floats may make quite a difference in take-off and seaworthiness.

Methods for determining the best shape of a hull or float for a given purpose are as follows:

(1) By tests of models in a towing basin (Model tests represent only one special case of seaplane operation, that is, planing in still water without the action of the pilot at the controls.)

(2) By comparison of various hulls that have already been built

(3) By full-scale tests of various floats on a seaplane especially designed for the purpose

A discussion of various factors in the design of seaplane hulls is given, with some empirical relations for determining the beam and length of the hulls.

19. Meyer, L.: Dimensions of Twin Seaplane Floats. NACA TM No. 719, 1933.

A study is made of a number of floats that have been approved by the Test Committee of Saint Raphael to discover such laws as may pertain to the design of twin seaplane floats. The following relationships were obtained by various calculations:

$$L = 5.1P^{0.37}$$
$$s = 0.24P^{0.83}$$
$$l = 0.62P^{0.5}$$
$$h = 0.5P^{0.33}$$
$$V = 0.82P^{1.2}$$

where

P gross weight, metric tons
L length, meters
s maximum section, square meters
$l$ maximum width, meters
h maximum height, meters
V volume, cubic meters

Upper and lower limiting values for the coefficient in each formula were found by comparison with full-size floats found to be good by the Test Committee.

20. Diehl, Walter S.: A Discussion of Certain Problems Connected with the Design of Hulls of Flying Boats and the Use of General Test Data. NACA Rep. No. 625, 1938.

A survey of the problems encountered in applying general test data to the design of flying-boat hulls is made. It is shown how basic design features may be readily determined from special plots of test data. A study of the effect of the size of a flying boat on the probable limits to be covered by the general test data is included and recommendations for special tests and new methods of presenting test data for direct use in design are given.

21. Magaldi, Giulio: Hulls for Large Seaplanes. NACA TM No. 295, 1925.

The design of hulls for seaplanes of successively increasing gross weight is discussed. Designing geometrically similar seaplanes, the scale varying either as the square root or cube root of the gross weight, is shown to lead to inadmissible results. The ratio of the gross weight to the square of the beam should increase slightly with the gross weight. Length, draft, and transverse cross section of floats, structural weight, and the design of twin hulls are discussed.

GENERAL INFORMATION
Design

22. Thornburg, F. L.: Hydrodynamics Manual – (A Digest of Available Information on Flying Boat Hulls). Rep. No. ZH-021, Consolidated Vultee Aircraft Corp., Nov. 1944.

Information on the hydrodynamics of flying boats from a bibliography of 42 different references has been compiled and presented. The material has been organized to show the effect upon performance of changes in length-beam ratio, forebody, afterbody, and the step. Other topics discussed include longitudinal steps, fluted bottoms, breaker steps, spray strips, sponsons, planing flaps, hydrofoils, wing incidence, tail damping, power loading, hull loading, center-of-gravity position, moment of inertia, radius of gyration, low-aerodynamic-drag hulls, and spray and wave suppression. Criterions and charts have been given where useful, and a fairly complete nomenclature has been included. Data and formulas used in hydrodynamic design have been tabulated.

23. Sumner, P. H.: Marine Aircraft. Crosby Lockwood & Son (London), 1930.

The size of flying boats has reached a stage where construction calls for the services of both the aeronautical engineer and the naval architect to create a seaplane wherein a compromise is made embodying good aerodynamic qualities with the requirements for proper functioning on the water. A summary of elementary naval architecture for the use of aeronautical engineers and draftsmen is presented. Many flying boats built in various countries are described, and aerodynamic and propulsive characteristics, displacement and buoyancy calculations, static stability, hull lines and lofting, systems of construction, and structural materials are briefly discussed.

24. Anon.: Navy Aeronautical Specification for the Design and Construction of Airplane Hulls. NAVAER SR-161, Bur. Aero., Aug. 6, 1945.

This specification embodies the general requirements of the Bureau of Aeronautics for the design of hulls for boat-type airplanes. Items discussed are: hull (general, strength, construction); beaching gear; required calculations, drawings, and data; water-tightness tests.

GENERAL, INFORMATION
Design

25. Pugsley, A. G., and Fairthorne, R. A.: Note on Airworthiness Statistics. Rep. No. A.D. 3123, British R.A.E., May 1939.

This note briefly discusses some general questions now arising in the analysis of statistical data such as are being collected on flying-boat alighting and take-off accelerations. The relations between such loading data and airplane accident statistics are indicated. Attention is drawn to the ultimate value of general work on this question both from the safety and the design standpoints.

26. Seewald, Friedrich: On Floats and Float Tests. NACA TM No. 639, 1931.

Some of the fundamental problems involved in float design are presented and discussed in detail. Steps that have been taken to solve these problems and suggestions for future research are presented. Among the subjects discussed are:

(1) The law of similitude and its boundary-layer considerations
(2) Trimming moments as they affect resistance and design
(3) Impact - its nature and how it is controlled
(4) The need for more complete towing-basin-model data in order to make possible reliable take-off calculations
(5) The application of design principles to floats

Of special interest is the analysis of the effect of longitudinal strips on impact. The longitudinal strips on a float effect an increase in the accelerated water mass. At the moment the strips dip into the water a certain amount of air space between strip and float bottom still exists. As soon as this whole space is filled with water a certain mass of water must suddenly be set in motion, whereby the strips prevent the flow past the edges in a manner similar in effect to the end plates on an airplane wing.

27. Ebner, H.: Problems Appertaining to Marine Aircraft. R. T. P. Translation No. 1910, British Ministry of Aircraft Production. (From Luftwissen, Bd. 9, Nr. 5, May 1942, pp. 142-154.)

After an introductory discussion of some general questions - for instance, arguments in favor of land or marine aircraft, flying boat or seaplane - various research problems concerning marine aircraft are dealt with. The problems of resistance including the shape of the float bottom and the take-off process are discussed, and the model test is described. The influence of scale in the model test is explained in detail by theory and experiment. Some questions concerning stability, in particular the problem of dynamic longitudinal stability (porpoising) and the questions of lateral stability on the water, are also discussed. Problems that arise when the aircraft is taxying and drifting on the surface of the water are briefly described. Finally, strength problems are investigated. After a brief sketch of the theory of landing shocks, the results of measurements of bottom pressure on floats and flying boats as well as measurements of elongation in float undercarriage struts are outlined. It is shown how a frequency evaluation of these measurements can be carried out and how conclusions concerning the influence of the various conditions of employment on the stress of the float undercarriage as well as on its time strength can be drawn.

28. Schnadel, Georg: Relations between Ship Design and Seaplane Design. NACA TM No. 645, 1931.

The requirements to be met in seaplane design are discussed and compared with those in ship design and it is pointed out that:

Seaplanes, because of their speed, seem especially adapted to supplement traffic by ship. Seaplanes have been lacking, however, to a considerable extent in safety, economy, and range. Their seaworthiness must be improved, especially since forced landings on the water cannot be avoided.

Seaplanes should be designed for long-range duty and should have high-aspect-ratio tapering wings with high wing loadings and large dihedral. Stability and seaworthiness on the water, good propeller location, adequate compartmentation, fire protection, adequate strength in a seaway, and adequate lift-saving and radio equipment are essential for safe operation.

29. Miller, J. W.: Report on VSO Seaplane Studies. Rep. No. X01-1229, Lockheed Aircraft Corp., Aug. 19, 1944.

Current seaplane design practice is reviewed in an effort to find a float which will combine maximum seaworthiness requirements with high-speed requirements. Several charts of current design values of forebody and afterbody length-beam ratios, load coefficient, spray density, and center-of-gravity position are presented.

GENERAL INFORMATION
Design

It was concluded that in order to attain the wide speed range desired a wing of unusually high lift ($C_{L_{max}} = 4$) would be necessary. A variation of NACA hull 84FF with ventilation was considered, with auxiliary floats for transverse stability.

30. Langley, Marcus: Seaplane Float and Hull Design. Sir Isaac Pitman & Sons, Ltd. (London), 1935.

The basic principles of marine aircraft are presented and various methods of approximation necessary for their application are pointed out. The student is familiarized with tank testing techniques and results. The general characteristics, proportions, and dimensions of flying boats are discussed and certain design criterions are cited.

31. Lewe, Victor: Shape and Strength of Seaplane Under-Structures with Special Regard to Seaworthiness. NACA TM No. 37, 1921.

The results of calculations of the stresses in the float-supporting struts of several twin-float seaplanes are discussed and loads are given for use in the design of such structures. Several types of supporting strut system for float seaplanes are shown.

32. Anon.: Single-Float Seaplanes. Flight, vol. XLVII, no. 1883, Jan. 25, 1945, pp. 102-103.

A brief investigation of the advantages of single-float arrangements for seaplanes takes into account the factors that influence single-float design. Variations of the design are illustrated by indicated features of the Vought-Sikorsky Kingfisher, the Curtiss Seagull, and the Nakajima Rufe 2.

33. Pegna, Giovanni: Some Ideas on Racing Seaplanes. NACA TM No. 691, 1932.

The seven racing seaplanes designed by the author are discussed in detail. The ideas set forth in the designs, the problems encountered, and the final disposition of the airplanes are noted. The designs included airplanes which had an engine and propeller that could be rotated upward to avoid low-speed spray, a central retractable float, hydrofoils, and a water propeller to supplement an air propeller in the displacement and bow spray range.

34. Baker, G. S.: Some Notes on Floats for Seaplanes of the Single Float Type. Fourteenth Series. R. & M. No. 437, British A.C.A., 1919.

The requirements to be satisfied in the design of a float for a seaplane are discussed. The discussion is based upon model experiments carried out at the William Froude National Tank.

The dynamic conditions discussed are diving at low speeds, seaworthiness in smooth and rough water, porpoising, transverse stability, trim at high speeds, and water resistance. The static conditions discussed are buoyancy and reserve buoyancy, longitudinal strength, and stresses on a float in a seaway.

(See also abstracts 8, 64, 173, 331, and 390.)

## Descriptions

35. Rohrbach, Adolf K.: Flying Boat Design. Aero. Engineering, Trans. A.S.M.E., vol. 2, no. 4, Oct.-Dec. 1930, pp. 285-288.

The five main problems in flying-boat design are size, aerodynamic qualities, floating system, structural principles, and general arrangement. The design of the Rohrbach Romar flying boat takes into account all these problems. It is of optimum size - 19.5 tons - and has good aerodynamic characteristics. The lateral stability provided by the inboard floats is such that a side wind of 30 miles per hour will not force the leeward wing into the water. The hydrodynamic qualities of the hull are such that take-offs have been made in waves of 12 to 15 feet.

GENERAL INFORMATION
Descriptions

36. Pegna, G.: High Efficiency of Seaplanes. NACA TM No. 32, 1921.

The Savoia S12 seaplane, the winner of an international seaplane contest, is shown to be superior to several other seaplanes and landplanes, judged on the basis of an index of efficiency Ir given by

$$Ir = \frac{QD}{C}$$

where Q is pay load, D operating range, and C weight of fuel and oil necessary to attain the range D. In the comparison one value of range, specific fuel consumption, and weight of crew was used for all the airplanes.

37. Dornier, C.: Lessons of the Do.X. Jour. R.A.S., vol. XXXVII, no. 273, Sept. 1933, pp. 757-782.

Three different examples of the flying boat Do.X are covered in this report: the original Do.X 1 aircraft fitted with air-cooled engines; the Do.X 1 fitted with water-cooled engines, referred to as Do.X 1a; and a third type with enclosed access to the engines and oil coolers combined with the water radiators, referred to as Do.X 2.

A full description is given of the Do.X 1a and its test flight to four continents. Emphasis is placed upon the design features that differ from English designs - stub wings and the storing of fuel in the hull. A description and photographs are included of the "trimming buckets" used for auxiliary lateral stabilization when the flying boat was moored in rough seas.

Some specifications of the aircraft are as follows:

| | |
|---|---|
| Maximum power | 7,400 hp |
| Maximum gross weight | 56,000 kg or approx. 124,000 lb |
| Maximum useful load | 24,800 kg or approx. 54,700 lb |
| Fuel consumption | 7.45 kg/km or approx. 26.5 lb per mile |

GENERAL INFORMATION
Descriptions

Cruising speed . . . . . . . . . . . . . . . . . . . . . . . 168 km/h or approx. 104 mph
Maximum range . . . . . . . . . . . . . . . . . . . . . . . 3,200 km or approx. 1,990 miles

It is interesting to note that in tropical climates the seaplane would not take off with a full load. Descriptions of accidents to stub wings and of fires are given along with description of repairs made away from prepared bases.

38. Seewald, F., Blenk, H., and Liebers, F.: The 1926 German Seaplane Contest. Part I - Lessons Taught (By Seewald). Part II - Method of Rating (By Blenk and Liebers). NACA TM No. 454, 1928.

I - The 1926 German seaplane contest was a technical contest designed to promote the building of efficient seaplanes of general usefulness. A criterion of excellence for each seaplane was computed, on the basis of tests of rate of climb and maximum horizontal speed, at the beginning of and at several times during a series of flights totaling 4000 kilometers (2486 miles). The ability of the seaplanes to take off and land in rough water was noted. It is pointed out that further technical contests rating the efficiencies of aircraft, as well as sporting contests rating the efficiencies of crews, should be encouraged.

II - From average or normal values of aerodynamic efficiency, propeller efficiency, and engine characteristics, the rate of climb, useful load, and gross weight may be used to calculate the maximum speed. The ratios of the actual speed to the calculated speed constituted a criterion of excellence of the seaplane.

39. Rohrbach, Adolf: Recent Experiments with Large Seaplanes. NACA TM No. 353, 1926.

The advantages to be obtained by use of large airplanes with high wing loadings are demonstrated by use of the Rohrbach Ro II, a monoplane flying boat of 6200 kilograms (13,700 lb) gross load with a wing loading of 88 kilograms (18 lb/sq ft) per square meter. The hull is narrow and of simple structure. Two large lateral floats at a short distance from the hull provide lateral stability. Twin

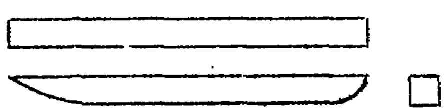
GENERAL INFORMATION
Descriptions

engines allow the seaplane to be turned easily on the water and thus facilitate handling. The wing structure consists of light leading-edge and trailing-edge sections attached to a box girder, the upper and lower surfaces of which conform to the airfoil section.

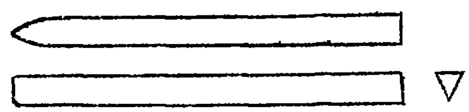
The advantages of increasing wing loading with size of airplane are shown. An analytical investigation of the effect of dihedral on the lateral motion of an airplane is given.

40. Sueter, Murray F.: Report of Experiments Carried Out with a Hydro-Aeroplane, with Notes and Suggestions for Further Experiments. R. & M. No. 69, British A.C.A., 1919.

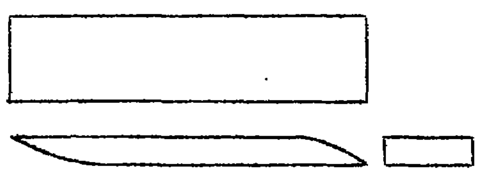
Several types of float were fitted to an Avro biplane to enable it to rise from the water under its own power. The Mark II float was a single float with small auxiliary floats at the wing tips; all of the others were twin-float arrangements. The airplane fitted with the Mark VII floats took off but crashed on landing. This flight is claimed to be the first off water in England. Two hydrofoils extending between the Mark IV floats gave a considerably large amount of lift but were easily fouled by seaweed. Several questions are listed about which information in regard to floats is needed.



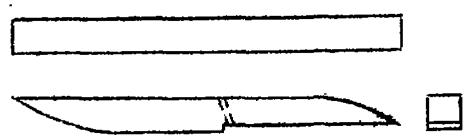
Mark I float



Mark IV float



Mark II float



Mark VII float

GENERAL INFORMATION
Descriptions

41. Weyl, Alfred Richard: The Schneider Trophy Contest. NACA TM No. 712, 1933.

The Schneider trophy contest is reviewed and a detailed description of the entries is given. The origin of the contest, the attitude of the governments participating, the reactions of the pilots, and the aerodynamic efficiencies of the seaplanes are discussed.

England won the contest chiefly because of a strong united effort. The contest provided an excellent stimulus for the improvement of airplanes and it has been said by one engine company that research for the Schneider race, carried on during two years, was equivalent to a normal development activity in their engine section of from six to ten years.

Take-Off

42. Parkinson, J. B., and Bell, J. W.: The Calculated Effect of Trailing-Edge Flaps on the Take-Off of Flying Boats. NACA TN No. 510, 1934.

The results of take-off calculations are given for an application of simple trailing-edge flaps to two hypothetical flying boats, one having medium wing and power loadings and consequently considerable excess of thrust over total resistance during the take-off run, the other having high wing and power loadings and a very low excess thrust.

For these seaplanes the effect of downward flap settings was: (1) to increase the total resistance below the stalling speed, (2) to decrease the get-away speed, (3) to improve the take-off performance of the seaplane having considerable excess thrust, and (4) to hinder the take-off of the seaplane having low excess thrust. It is indicated that flaps would allow a decrease in the high angles of wing setting necessary with most seaplanes, provided that the excess thrust is not too low.

GENERAL INFORMATION
Take-Off

43. Olson, R. F., and Allison, J. M.: The Calculated Effect of Various Hydrodynamic and Aerodynamic Factors on the Take-Off of a Large Flying Boat. NACA Rep. No. 702, 1940.

An investigation was made of the influence of various factors on the take-off performance of a hypothetical large flying boat by means of take-off calculations. The factors varied in the calculations were size of hull (load coefficient), wing setting, trim, deflection of flap, wing loading, aspect ratio, and parasite drag.

The take-off times and distances were calculated to the stalling speeds and the performance above these speeds was separately studied to determine piloting technique for optimum take-off. It was found, for the flying boat investigated, that:

(1) The final selection of the load coefficient, within a fairly large range of values, could be based on considerations other than the calculated take-off performance.

(2) The angle of wing setting giving the minimum total resistance at 85 percent of the stalling speed is still a good compromise wing setting. The use of flaps in take-off tends to reduce the loss in performance obtained with a low angle of wing setting.

(3) Deviations of more than $1\frac{1}{2}^\circ$ above or $1^\circ$ below the trim for minimum water resistance result in large increases in the time and the distance of the take-off. A method of determining a precision take-off giving the optimum performance is suggested.

(4) The net effect of the flaps was to improve the take-off performance, which becomes more important as the wing loading increases. There is little advantage in using deflections of the flaps much greater than $15^\circ$. A method of improving the take-off performance by using a delayed deflection of the flaps is suggested.

(5) With high wing loadings, the resistance at high speeds becomes increasingly important. High angles of wing setting, wings of high aspect ratios, low parasite drag, and the use of flaps improve the calculated take-off performance.

GENERAL INFORMATION
Take-Off

44. Crowley, J. W., Jr., and Ronan, K. M.: Characteristics of a Boat Type Seaplane during Take-Off. NACA Rep. No. 226, 1926.

The planing and get-away characteristics of the F-5-L were investigated by the National Advisory Committee for Aeronautics; the results of the second of a series of tests on three different seaplanes are presented. The single-float seaplane was the first tested (abstract 45) and the twin-float seaplane is to be the third.

The characteristics of the boat-type seaplane were found to be similar to those of the single-float seaplane, the main difference being the increased sluggishness and the relatively larger planing resistance of the larger seaplane. At a water speed of 15 miles per hour the seaplane trims up to about 12° and remains in this angular position while plowing. At 22.5 miles per hour the planing stage is started and the planing angle is immediately lowered to about 10°. As the velocity increases, the longitudinal control becomes more effective but overcontrol will produce instability. At get-away the range of angle of attack is 19° to 11° with velocities from the stalling speed through about 25 percent of the speed range.

45. Crowley, J. W., Jr., and Ronan, K. M.: Characteristics of a Single Float Seaplane during Take-Off. NACA Rep. No. 209, 1925.

The National Advisory Committee for Aeronautics at Langley Field, Va., investigated the planing and get-away characteristics of an N-9H, a DT-2, and an F-5L as representing, respectively, a single float, a double float, and a boat-type seaplane. The present report covers the investigation conducted on the N-9H. The results show that a single-float seaplane trims up in taking off. Until a planing condition is reached, the angle of attack is about 15° and is only slightly affected by the controls. When planing, the float seeks a lower angle but is controllable through a widening range, until at the take-off it is possible to obtain trims from 8° to 15° with corresponding speeds of 53 to 41 miles per hour or about 40 percent of the speed range. The point of greatest resistance occurs at about the highest trim, a float planing angle of $9\frac{1}{2}^{\circ}$, and at a water speed of 24 miles per hour.

GENERAL INFORMATION
Take-Off

46. Crowley, John W., Jr., and Ronan, K. M.: Characteristics of a Twin-Float Seaplane during Take-Off. NACA Rep. No. 242, 1926.

An investigation has been made by the National Advisory Committee for Aeronautics of the planing and get-away characteristics of three representative types of seaplanes: namely, single float, boat, and twin float. The experiments carried out on the single float (abstract 45) and boat types (abstract 44) have been reported previously. The present report covers the investigation conducted on the twin-float seaplane and includes, as the appendix, a brief summary of the results obtained in all three tests.

The fundamental take-off characteristics of the DT-2 (twin-float seaplane) are similar to those of the N-9H (single-float seaplane) and the F-5L (boat seaplane). At low water speeds, 20 to 25 miles per hour, the seaplane trims by the stern and has a high resistance. Above these speeds the longitudinal control becomes increasingly effective until, with a gross load of 6000 pounds, it is possible to get away at angles of attack of 8° to 14° with corresponding speeds of 56 to 46 miles per hour. It was further determined that an increase in load caused little, if any, change in the water speed at which the maximum trim and resistance occurred but did produce an increase in the maximum trim.

47. Nutt, A. E. Woodward, and Richards, G. J.: Cine-Photographic Measurements of Speed and Attitude of Southampton Aircraft When Taking Off and Alighting. R. & M. No. 1621, British A.R.C., 1935.

The possibility of determining the take-off and landing speeds of seaplanes by means of photographs taken from land with a motion-picture camera has been investigated and the lift coefficients of seaplanes while taking off and landing have been compared with those measured in flight.

Motion pictures were taken of a large number of take-offs and landings of four Southampton flying boats, and the pictures of 45 runs were analyzed. The take-offs and landings were made with, against, and across winds of various measured speeds. The true airspeeds, angles of incidence, and lift coefficients of the seaplanes at the instants of take-off or landing were deduced from the film records.

GENERAL INFORMATION
Take-Off

Accurate measurement of the take-off and landing speeds of seaplanes by this method is limited by wind gustiness and by the difficulty of determining accurately the wind speed at the time and place of testing. The present experiments indicate that under normal conditions the probable error in any individual measurement of the take-off or landing speed of a normal seaplane by this method is approximately ±1.4 knots. Improved methods of measuring wind speed may increase this accuracy for future tests.

The lift coefficients for the Southampton flying boats at the instant of take-off or landing over a wide range of incidence are considerably higher than those found for similar flying boats in free flight. This increase appears to be the same for take-off and landing, irrespective of the direction of the runs in relation to that of the wind. In those respects the results are in general agreement with those found at the Aeroplane and Armament Experimental Establishment for landplanes.

48. Shaw, R. A.: The Effect of Flaps on the Take-Off of Flying Boats. Part I. Tests on the Saro 37. Rep. No. H/Res/143, British M.A.E.E., July 3, 1941.

Tests are being made at the Marine Aircraft Experimental Establishment to investigate the effect of flaps on the take-off of flying boats. The tests have been begun on the Saro 37, which is a small high-wing monoplane flying boat fitted with slotted flaps. Attitude and acceleration have been measured in a series of take-offs with flap angles up to 45°. The behavior in the initial climb has also been reported. The results have been analyzed to show the effect of flaps on acceleration, trim, take-off speed, and rate of climb.

The best acceleration during the run and the best rate of climb are both obtained with flap neutral. The results with small flap settings are only slightly inferior, but both acceleration and rate of climb fall off considerably as the flaps are lowered to big angles. Acceleration is sensitive to attitude at all flap settings. Lowering the flaps to 45° gives a nose-down moment during the run equal to 10° and a nose-up moment in the climb equal to 5° of elevator movement. The take-off speed is reduced progressively as the flaps are lowered, and the technique which makes best use of the flaps is to begin the run with flaps up and to lower them only for take-off.

GENERAL INFORMATION
Take-Off

It was interesting to note that in the early part of the take-off, the flying boat showed a marked tendency to swing to the starboard with flap deflections greater than 15°. Yawing was prevented by using the elevators to press the afterbody into the water.

49. Shoemaker, James M., and Dawson, John R.: The Effect of Trim Angle on the Take-Off Performance of a Flying Boat. NACA TN No. 436, 1934.

Data obtained at Langley tank no. 1 from tests of models of three flying-boat hulls - NACA models 11-A, 16, and 22 - are used to demonstrate the effect of trim on water resistance. From the examples presented, the following conclusions may be drawn:

(1) The angle of wing setting selected to give the least total resistance at 85 percent of the stalling speed will be satisfactory throughout the take-off run.

(2) The trim giving the minimum water resistance will also give the least total resistance, and deviations of more than 2° or 3° from best trim will result in a serious increase in take-off time and distance.

(3) The best trim for a given water speed with a head wind of less than 15 knots does not differ by more than 1° from the best trim with no wind.

Piloting and the importance of maintaining best trim throughout the take-off are discussed. A trim-indicating instrument for use on seaplanes is described.

50. Diehl, Walter S.: The Estimation of Maximum Load Capacity of Seaplanes and Flying Boats. NACA Rep. No. 453, 1932.

It is shown that the relation between the gross weight $W$ and the time for take-off $t$ of seaplanes and flying boats is of the form

$$W_m = W + K \frac{b.hp}{t}$$

GENERAL INFORMATION
Take-Off

where $W_m$ is the maximum possible load corresponding to infinite value of $t$, b.hp is the total brake horsepower, and $K$ is a constant. Data from four tests give $K = 140$.

This equation supplies a method of calculating time for take-off with any load, or vice versa, when the time for one load is known.

51. Verduzio, R.: Hydrodynamic Tests for Determining the Take-Off Characteristics of Seaplanes. NACA TM No. 204, 1923.

The inability of a seaplane to take off is often discovered only in the actual test of the complete seaplane. A graphical method of determining the take-off characteristics of a seaplane is given. The total resistance, determined from tank and wind-tunnel tests of a model of a seaplane float, is plotted as a function of speed. If the total resistance is always less than the thrust, the seaplane can take off.

52. Courtney, Frank T.: Land Launched Seaplanes. Aviation, vol. 35, no. 9, Sept. 1936, pp. 19-21.

A system is proposed for launching heavily loaded flying boats. Estimates are made for a normal flying boat of 40,000 pounds gross weight with a wing loading of 30 pounds per square foot to take off at 67,000 pounds gross weight with a wing loading of 50 pounds per square foot for long-range purposes. An acceleration between $\frac{1}{4}$ and $\frac{1}{2}g$, a launching run of 3000 feet, towing the launching carriage by means of cables operated by a stationary engine, a tilting platform and turntable for the airplane, and a method of control from the cockpit are suggested. Such a launching system would be of immense military and commercial value.

53. Outman, Vernon: A Method of Calculating Seaplane Take-Off. Aero. Digest, vol. 32, no. 6, June 1938, pp. 53, 54, 59, 60.

A method of calculating seaplane take-off is described with the aid of numerous charts and tables. This method not only enables computations of take-off time and distance but also offers a means

GENERAL INFORMATION
Take-Off

of studying the effect of the various factors, including those influencing trim.

"General method" hydrodynamic test data are used in conjunction with assumed aerodynamic data. From an assumed load and a series of assumed elevator positions, the aerodynamic moments are calculated and equated to the hydrodynamic moments. From the resulting equilibrium trims, the total resistances can be obtained. A curve of total resistance against speed is then obtained for the best take-off condition with the available elevator control. From this curve, the excess thrust is determined and $1/a$ and $V/a$ are computed, where $a$ is the acceleration and $V$ is the velocity. Values of $1/a$ and $V/a$ are then plotted against $V$, and the areas under the curves are the take-off time and the distance, respectively.

54. Hutchinson, J. L., and Bird, J. H.: Note on the Correction of Measured Take-Off of Seaplanes to Tropical Conditions. Rep. No. H/Res/182, British M.A.E.E., Sept. 18, 1944.

A method of estimating the tropical take-off performance of seaplanes from the performance in temperate conditions, based on Hufton's treatment of the corresponding landplane problem, has been developed. The method is applicable to the general problem of correction of take-off performance for atmospheric pressure and temperature.

The method can be used for take-offs at full throttle or at constant boost and requires a knowledge of engine power at take-off and propeller data. Estimations of air drag and water resistance are avoided.

55. Morris, W.: Note on the Take-Off Characteristics of the Sunderland Flying Boat. Rep. No. F/Res/123, British M.A.E.E., Sept. 28, 1938.

Longitudinal acceleration and attitude have been measured during take-offs of a Sunderland flying boat. The attitude is found to be very low compared with that obtained in the tank tests; the maximum difference is approximately $4^{\circ}$ at the hump.

GENERAL INFORMATION
Take-Off

56. Brooke, H. E.: Report on the Use of Jet Propulsion to Assist the Take-Off of the PB2Y-3 Airplane. Rep. No. ZH-29-012, Consolidated Aircraft Corp., Dec. 8, 1942.

Consideration was given to the use of jet assistance for the take-off of the PB2Y-3 flying boat. The jets were assumed to be mounted in the step rise and therefore not to contribute any drag.

The studies indicated that three jets, producing 2000 pounds thrust each, would provide sufficient additional acceleration to permit a satisfactory take-off with 76,000 pounds gross weight. The reductions in take-off time with the jets in operation for the full take-off period were tabulated.

57. Rogers, M.: Report on the Use of Jet Propulsion to Assist the Take-Off of the XP4Y-1 Airplane. Rep. No. ZH-31-016, Consolidated Aircraft Corp., Nov. 13, 1942.

A brief take-off, weight, and installation study has been made for the XP4Y-1 airplane equipped with two 1000-pound-thrust jet-assistance units. The jets have been assumed to be mounted in the nacelles; however, installations in the hull afterbody and in the step have been considered. The jets were suggested to facilitate take-off at overloads and to permit an emergency increase in speed at an altitude of 13,600 feet.

The jets did not decrease take-off time enough to warrant their use at 46,000 pounds (normal) gross load, but at 55,000 pounds gross load the take-off time was reduced 22 seconds. At an altitude of 13,600 feet the top speed was found to increase from 255 miles per hour to 295 miles per hour within a period of 2 minutes with continuous jet action. In this case, the use of jets is infeasible because of the additional weight that must be carried.

If the same thrust is assumed to be obtainable under water as in air, the most advantageous position of the jet units appeared to be in the step.

58. Pierson, John D., and Burghardt, Joseph E.: A Specific Chart for Flying Boat Take-Off Performance. Jour. Aero. Sci., vol. 12, no. 2, April 1945, pp. 169-172.

The take-off performance of a flying boat is complicated in practice by the variety of possible combinations of the basic

GENERAL INFORMATION
Take-Off

operating variables - weight, power, wind, and get-away speed. The desirability of a simple method of evaluating and presenting the required information is evident in view of the labor involved in computing performance for all the possible combinations of conditions involved.

From early studies of Diehl and others and from later correlations of take-off data (both calculated and flight test), it has become clear that there exists an approximately linear relationship between the reciprocal of the take-off time and the four operating parameters listed above. It is empirically shown in this paper that, in addition, the take-off distance is directly proportional to the product of take-off time and get-away speed.

These relationships form the basis for a new type of chart for the prediction of the take-off time and distance for a specific flying boat under any reasonable combination of the operating variables or for the reduction of flight-test data to a standard of comparison.

59. Diehl, Walter S.: A Study of Flying-Boat Take-Off. NACA TN No. 643, 1938.

It is shown that the normal resistance curve for a flying boat may be approximated by two straight lines. The equations for take-off distance and time, derived from this approximation, are applied to a series of flying boats and the resulting factors are plotted in nondimensional form in a series of charts. Take-off performances from the charts are shown to be in good agreement with step-by-step integrations. Some applications of the charts to the solution of general design problems are included.

60. Stout, Ernest G.: Takeoff Analysis for Flying Boats and Seaplanes. Part I. Aviation, vol. 43, no. 8, Aug. 1944, pp. 150-153.

Because of a confusing conglomeration of charts, formulas, and rules of thumb, a clear sound analysis of seaplane take-off is timely. Flying-boat take-off is broken down into four phases, which are discussed in some detail. The nomenclature and the equations necessary for the computation of take-off time and distance are given. A conventional computation procedure is outlined with the aid of charts and tables.

61. Inverarity, W. M.: Tests of a Flap Preselector on Sunderland I. Rep. No. H/Res/172, British M.A.E.E., Jan. 31, 1944.

Take-off tests have been made with a flap preselector fitted to a Short Sunderland I flying boat. In operation the preselector functioned satisfactorily.

The slow rate of travel and the small flap angles attainable precluded large improvements in take-off performance. By preselecting to 2/3 flap and switching on around 50 knots, a small gain - about 10-percent reduction - in take-off speed was obtained with corresponding improvements in take-off time and distance.

62. Schröder, P.: Towing Tests of Models as an Aid in the Design of Seaplanes. NACA TM No. 676, 1932.

Seaplane take-off is discussed and a method of calculating the take-off time and distance is described with reference to a specific example.

"General method" hydrodynamic test data are used in conjunction with aerodynamic data obtained from model tests. By using lift as the sum of the wing lift and the thrust lift, the weight on the water is calculated and plotted as a function of speed with angle of attack as a parameter. The resistances and moments are found for each trim. The aerodynamic trimming moments (thrust + tail moment) are equated to the hydrodynamic moments and the resulting trims are interpolated. A calculation is made of elevator effectiveness in order to determine the possibility of maintaining best trim at high speeds. The increase in load on the water due to tail load is accounted for and a final check is made on the computations. The air drag is added to the water resistance and the excess thrust is determined. The values of $1/a$ and $V/a$ (where $a$ is acceleration at any speed) are computed and plotted against the velocity $V$; the areas under the curves are the take-off time and distance, respectively.

GENERAL INFORMATION
Take-Off

63. Gough, Melvin N.: The Use of the Trim-Angle Indicator for Seaplane Take-Off. Jour. Aero. Sci., vol. 4, no. 7, May 1937, pp. 288-291.

The angle of trim is shown to be of great importance in the take-off of a seaplane. As the events of the take-off are now almost completely controllable, the pilot should have some means for determining the trim. The optical trim-angle indicator has been suggested by the National Advisory Committee for Aeronautics. The use of the indicator requires but little diversion of the pilot's attention. It has proved necessary for the pilot to keep only two angles and one speed in mind during take-off - the angles for the hump and for planing and the airspeed for get-away. At the beginning of take-off, the nose is allowed to rise with increasing speed until the angle is reached at which the hump should be passed. Full-down elevator is then applied to hold the required trim until the hump is passed. At planing speed, the control force is usually rearward to hold the best planing trim until get-away. It was observed that pilots usually pass the hump at too high an angle and plane at too low an angle.

(See also abstracts 112, 124, 164, 172, 331, and 401.)

Bibliographies

64. Benson, James M., and Bidwell, Jerold M.: Bibliography and Review of Information Relating to the Hydrodynamics of Seaplanes. NACA ACR No. L5G23, 1945.

A bibliography and a review of information relating to the hydrodynamics of seaplanes have been presented. Data and conclusions obtained from the references in the bibliography have been correlated to present in qualitative form a summary of the status of knowledge pertaining to the hydrodynamics of seaplanes and to point out the need for further research. Characteristics of conventional hulls and floats are discussed to show the effects upon performance of changes in design parameters such as dead rise, depth of step, and angle of afterbody keel. A separate section has been devoted to special problems relating to floats for seaplanes. Other topics discussed

GENERAL INFORMATION
Bibliographies

include lateral stabilizers, aerodynamic and propulsive considerations, unconventional configurations, hydrofoils, and piloting and handling.

The arrangement of the bibliography in general is similar to that of the text. References on flying-boat hulls, planing surfaces, and seaplane floats, however, have been listed separately in the bibliography. Reference material pertaining to impact loads has been included in the bibliography although the subject has not been reviewed. Information on experimental procedures used to obtain the results discussed in the text may be found in the references in the concluding section of the bibliography.

65. Bibliography of Aeronautics. Part 5 – Seaplanes. Part 6 – Flying Boats. Part 7 – Amphibians. U.S. Works Progress Adm., 1938.

This bibliography is one of a series which aims to cover a large part of aeronautical literature. It was compiled from the Index of Aeronautics of the Institute of the Aeronautical Sciences and includes books, papers, and articles published in and before 1938.

The bibliography has been divided primarily into three parts: Seaplanes, Flying Boats, and Amphibians. The references have been arranged under the headings: Design and Construction, Development, Floats (or Hulls), Performance and Testing, and Seaplanes Classified by Manufacturer. The references are listed in the reverse chronological order of their publication.

66. Bibliography of Aeronautics. Supplements to: Part 5 – Seaplanes. Part 6 – Flying Boats. Part 7 – Amphibians. Works Projects Adm., Oct. 1940.

This supplement extends the original bibliography (abstract 65) by listing books, papers, and articles published between 1938 and 1940.

(See also abstracts 22 and 305.)

HYDROSTATICS
General

67. Griffey, W. J.: Favoring the Classical in Flying Boat Hydrostatics. Aviation, vol. 43, no. 10, Oct. 1944, pp. 159-163.

The proponents of the experimental method for determining static qualities of a flying-boat hull are challenged, and the facility and speed with which traditional methods of naval architecture may be applied are shown in detail. With the aid of several charts, figures, and formulas, sample calculations are made for the trim and draft of the hull and the size of the wing-tip floats.

(See also abstracts 22, 64, and 393.)

Buoyancy

68. Parkinson, H.: Notes on the Design of Twin Seaplane Floats. The Aircraft Engineer, supp. to Flight, vol. XXV, no. 1261, Feb. 23, 1933, pp. 12-14.

A shortened method for the design of twin seaplane floats is presented. Values are assumed for reserve buoyancy, length-beam ratio, height ratio, block coefficient, and load, and an example calculation is made for the lines, dimensions, and track. The several design curves used in the calculations are included.

(See also abstracts 23, 34, 67, and 393.)

Stability

69. Warner, Edward P.: The Calculation of Wing Float Displacement in Single-Float Seaplanes. NACA TN No. 215, 1925.

In a calculation of the proper size of wing floats for flying boats, the stability of the main float is often entirely neglected - the position of center of buoyancy being assumed independent of the angle of inclination. When a fixed reserve of buoyancy is used in transverse stability calculations, the results are liable to be incorrect. The reserve buoyancy in the case of the NC flying boat was 490 percent. Better results would be obtained if the float were large enough to hold the wing out of the water if the metacentric height were increased by a certain number of feet.

70. Parkinson, H.: Longitudinal Stability Calculations of Seaplanes on Water. The Aircraft Engineer, no. 104 (vol. IX, no. 9), supp. to Flight, vol. XXVI, no. 1344, Sept. 27, 1934, pp. 69, 70.

Seaplane static longitudinal stability characteristics are most easily obtainable when a tank and models are available, but in the absence of such equipment a graphical method can be used which will reduce the voluminous calculations required by the more classical Simpson's Rule.

A water line is assumed for a specific trim and the sectional area is plotted as a function of distance from the bow. The volume, and thence the displacement, is obtained by integrating this curve. The moment of the area about the stern is plotted as a function of the distance from the bow. Integration of the moment curve produces the moment of volume which when divided by the displaced volume yields the righting lever of the righting moment. Subsequent calculations allow a curve of righting moment against trim angle to be plotted from which the stability characteristics of floats may be determined.

71. Vladimirov, A. N.: Standards of Transverse Stability for Flying Boats. R.T.P. Translation No. 1155, British Ministry of Aircraft Production. (From Aero. Engineering, U.S.S.R., vol. 14, no. 4/5, April/May 1940, pp. 62-70.)

Formulas in use for obtaining transverse stability are based upon data from flying boats of different types and varying degrees of seaworthiness, also from types of which the stability may have been incorrectly estimated. By comparing the righting moments given by these formulas with the righting moments of existing flying boats, it has been found that almost all these foreign standard formulas give a far higher value of the righting moment than necessary.

A formula, derived from an analysis of data taken from flying boats possessing sufficient transverse stability in service, has been suggested. The formula has accounted for the inherent instability of the flying boat (negative metacentric height) and for the effect of propeller torque, side wind, and waves. Standardization of the design criterion has been established by relating the velocity of side wind to the gross weight of the boat; large boats are more seaworthy than small ones. A range of seaworthiness constants has been given to permit floats to be designed for different conditions of operation.

72. Diehl, W. S.: Static Stability of Seaplane Floats and Hulls. NACA TN No. 183, 1924.

The lateral stability of twin-float seaplanes and single-float seaplanes with wing-tip floats is discussed. Data for computing the lateral stability of several seaplanes and flying boats are presented. The longitudinal and lateral metacentric heights of seaplanes are approximately concluded to be straight-line functions of the gross weight, and the suggestion is made that in new designs they be made equal to each other and have a value

$$GM = 15 + 0.002\ W$$

where the metacentric height GM is in feet and the gross weight $W$ is in pounds.

73. Anon.: Transverse Stability of Seaplanes. Aircraft Engineering, vol. V, no. 57, Nov. 1933, pp. 271-273.

The transverse and longitudinal stability of the twin-float-type seaplane at rest is examined and discussed. With the empirical rules that the transverse metacentric height in feet must not be less than (gross weight)$^{1/3}$ and the longitudinal metacentric height in feet must not be less than 1.75 (gross weight)$^{1/3}$, an example calculation is made to determine the width of track required for stability.

(See also abstracts 16, 23, 67, 173, 199, and 212.)

HYDRODYNAMICS
General

74. Ackeret, J.: Experimental and Theoretical Investigations of Cavitation in Water. NACA TM No. 1078, 1945.

Cavitation in nozzles, on airfoils of various shape, and on a sphere are experimentally investigated. The limits of cavitation and the extension of the zone of the bubbles in different stages of cavitation are photographically established. The pressure in the bubble area is constant and very low, jumping to high values at the end of the area. The analogy with the gas compression shock is adduced and discussed. The collapse of the bubbles under compression shock produces very high pressures internally, which may be contributory factors to erosion. The pressure required for erosion is discussed.

75. Escande, Léopold: Sur la similitude des phénomènes d'entraînement d'air par l'eau en mouvement. Comptes Rendus, t. 209, no. 17, Oct. 23, 1939, pp. 626-627.

In continuation of previous work the principle of similitude is shown to be theoretically not applicable to systems comprising a free surface subjected to atmospheric pressure, even if it be assumed that perturbations attributable to viscosity are negligible owing to turbulence, and if the effect of surface tension is not taken into account. The case of the entrainment of air by a stream of water is discussed in illustration of this contention.

76. Locke, F. W. S., Jr.: A Survey of the Factors Contributing to the Landing and Take-Off Accidents to U.S. Navy Flying Boats in the Last Twenty-Two Months. A.D.R. Rep.. M-32, Bur. Aero., Dec. 1944.

A survey was made of landing and take-off accidents of flying boats and amphibians on water occurring after January 1, 1943, which could possibly be considered as partially due to water handling characteristics of the hull. The accidents were broken down into those attributable to low-speed maneuverability, bow design, diving, waterlooping, rough-water damage, high-speed lower-limit porpoising, skipping, upper-limit porpoising, and tip-float design. A few cases of the different types of accidents were discussed in some detail and photographs of the resulting damage were included.

77. Squire, H. B., Harper, D. L., Bekassy, J., and Chester, W.: Wind Tunnel Tests of Oblique Jet Units. Rep. No. Aero 2007, British R.A.E., Jan. 1945, appendix.

The phenomenon of the adhesion of an air jet to a neighboring surface, which occurs under certain conditions, is called the Coanda effect after its discoverer. The initial adhesion of the plane jet is linked with the entrainment of air into an unobstructed plane jet. If the entrainment on one side is prevented by an obstruction, a reduction of pressure in the region between jet and obstruction occurs; the pressure difference created will divert the jet and adhesion will occur under favorable conditions. Reducing the aspect ratio of the jet increases entrainment from the ends and tends to reduce the Coanda effect. The phenomenon was observed for a wide range of angles of jet incidence, radius of curvature of the obstacle, and spacing between jet and obstacle.

(See also abstracts 22 and 64.)

Sustentation - Steady Planing

78. Sottorf, W.: Analysis of Experimental Investigations of the Planing Process on the Surface of Water. NACA TM No. 1061, 1944.

Flat and V-bottom longitudinally straight planing surfaces are investigated. For such surfaces the total resistance may, for a given

HYDRODYNAMICS
Sustentation - Steady Planing

lift, be separated into a normal and frictional component. The analysis of the tests leads to representations of the lift and center-of-pressure position as functions of the aspect ratio of the pressure area with the Froude number, which characterizes the effect of gravity, as parameter. The frictional resistance coefficient is equal to that given by Prandtl for the turbulent boundary layer with preceding laminar layer. For high Froude numbers, where the contribution of gravity to the lift is negligibly small, there is shown to be an agreement between the planing surface tests and the lift on flat airfoils on the underside. The deviations from the Wagner theory for short plates at large aspect ratios are considerable though justified by the conditions neglected in the theory.

With the aid of a working chart a number of practical examples are computed that provide the answers to several important questions. For the case of the flat plate the width of the plate, which is always the full width of the planing surface, has an effect on the resistance-load ratio in that the latter becomes more favorable with increasing width.

With regard to the load effect, on account of the impairment in the aspect ratio, there is an impairment in the resistence-load ratio with increasing load.

With regard to the effect of the speed, however, on account of the improvement in the aspect ratio with increasing dynamic pressure above the first resistance maximum, there is an improvement in the resistance-load ratio with increasing speed.

The tests for the scale effect show that there is similarity of the pressure surfaces and pressure distribution and that the effect of the scale is given only by the dependence of the friction coefficient on the Reynolds number. Only for very small dimensions and loads of the planing surfaces does nonsimilarity occur in the flow conditions because of the effect of surface tension.

The impairment in the resistance-load ratio by the effect of the V-bottom is also shown. With regard to the effect of the width it is found for the V-bottom that at small load or high dynamic pressure and with the "natural width," which is less than that of the planing surface, an optimum width occurs which is to be determined for each particular case.

HYDRODYNAMICS
Sustentation - Steady Planing

79. Landweber, L., and Eisenberg, P.: Characteristic Curves for Planing Surfaces. Rep. R-80, David Taylor Model Basin, Navy Dept., Jan. 1943.

The results given in abstract 87 are presented in a form similar to that used in presenting characteristic curves of an airfoil. This form of presentation facilitates the use of planing data for problems involving the towing of a planing float.

80. Bollay, William: A Contribution to the Theory of Planing Surfaces. Proc. Fifth Int. Cong. Appl.Mech. (Cambridge, Mass., 1938), John Wiley & Sons, Inc., 1939, pp. 474-477.

This paper presents a theory of planing surfaces by means of an airfoil analogy. A planing surface of infinite length and finite span was used for the discussion.

From Wagner's theory, for a gliding surface of infinite aspect ratio the normal force is 50 percent of the force on the corresponding wing, while the present theory has yielded the result that for a gliding surface of zero aspect ratio the normal force is 44 percent of the force on the corresponding wing. The wing-theory analogy therefore seems to hold for the entire range of aspect ratios.

81. Schröder, P.: Determination of Resistance and Trimming Moment of Planing Water Craft. NACA TM No. 619, 1931.

A theory is presented by which it becomes possible to determine the resistance and the trimming moment for any loading of a planing aircraft when these values are given for one load. The theory is presented, with experimentally substantiated examples, in three cases: (1) a constant given load and a constant required load, (2) a constant given load and a required load varying with velocity, and (3) both given and required loads varying with velocity.

82. Sottorf, W.: Experiments with Planing Surfaces. NACA TM No. 661, 1932.

A discussion of planing surfaces as a fundamental approach to hydrodynamic research is presented based on tests in which the

[redacted]

HYDRODYNAMICS
Sustentation - Steady Planing

resistance characteristics of flying-boat models were investigated with different planing bottoms and with different scales. The various testing techniques and apparatus used in the experiments are described.

A flat glass planing surface was towed at several loads and speeds. The results are plotted and compared with calculated results employing Prandtl's friction formula for a turbulent boundary layer with laminar approach. A noticeable difference is found to occur at high loads and low angles of attack and is attributed to decreasing aspect ratios. The planing surface was fitted for 35 orifices, which were connected to a multiple manometer. From experiments at various loading and trimming conditions, the pressure and velocity distributions were calculated. An attempt is made to break down the form resistance mathematically into induced resistance and wave resistance but an analysis of wave resistance is found to be impracticable. It is stated that only systematic research can produce the necessary bases for the predetermination of the resistance, moment, and trim of any gliding body.

83. Sottorf, W.: Experiments with Planing Surfaces. NACA TM No. 739, 1934.

Tank tests were made of planing surfaces and floats to determine the effect of converting model results to full size and the effect of the main form variables on the resistance, trimming moment, wetted area, pressure distribution, and spray profiles.

There is a pronounced scale effect in converting model resistance to full size when the models are so small that the change in frictional coefficient is great. The effect of surface tension on the height and form of the spray is important only when very small models are employed. Although a similarity of pressure distribution is found to exist for the several surfaces, the trim varied considerably for the small models.

It is noted that, for a given beam, increased dead rise increases the wetted area and hence the resistance. A comparison of the transverse pressure distributions for flat and V-bottom surfaces shows that at the same loads V-bottom surfaces have greater draft and therefore greater buoyancy. When higher angles of dead rise were employed, the

HYDRODYNAMICS
Sustentation - Steady Planing

spray, resistance, and pressure distributions appeared to be somewhat similar to those obtained from a displacement craft.

Chine flare, in general, tends to decrease the adverse effects of dead rise and for a surface having an angle of dead rise of $10^{\circ}$ the use of chine flare resulted in lower resistance than that of a corresponding flat surface at angles in excess of $6^{\circ}$. Large amounts of chine flare developed a stronger, higher, and more voluminous spray, delayed the appearance of pure planing, and were of no use in any way. Chine flare resulted in a more unfavorable spray even though the length of chine from which the spray appears was less. The best form was one in which the transition from the side to the horizontal occurred at a gradual rate.

Longitudinal curvature improves the longitudinal pressure distribution and allows a shorter wetted length for a given lift. The shorter wetted length results in decreased frictional resistance and a shorter length from which spray will appear. The spray at the sides is less in height and volume and the trough is deeper and wider than that of the longitudinally flat surface.

It should be noted that a large amount of basic planing data is included.

84. Perring, W. G. A., and Johnston, L.: Hydrodynamic Forces and Moments on a Simple Planing Surface and on a Flying Boat Hull. R. & M. No. 1646, British A.R.C., 1935.

An analysis has been made of the force and moment measurements for a plate planing on the water and expressions have been written down showing how these water reactions vary with the aspect ratio of the plate and also with the angle of V of the planing bottom. The effect of longitudinal and transverse curvature of the planing surface on the forces and moments has also been investigated. In addition the forces and moments have been related to the area of the projected still-water surface. An analysis has also been made of the hydrodynamic forces and moments determined from model tests on a typical seaplane hull.

The analysis has shown that the forces and moments on a planing surface can be represented by relationships similar to those of an airfoil. The lift was found to vary directly with incidence, the

HYDRODYNAMICS
Sustentation - Steady Planing

slope of the lift-coefficient curve being a function of the aspect ratio of the form $C\,A^{0.42}$. A similar relationship was also found to hold for V-shaped surfaces, the effect of the V-angle being to modify the coefficient C. The analysis of the drag showed that the forces on a planing surface could be regarded as comprising a force normal to the plane and a frictional force along the plane, which varied with the Reynolds number of the test. For flat rectangular surfaces the center of pressure was approximately at 0.73 of the immersed length from the trailing edge, and expressions were also found showing how the position of the center of pressure varied with longitudinal curvature and with the ratio of the immersed lengths of chine and keel of a V-shaped surface. The analysis was extended to obtain relationships which enable the lift, drag, and pitching moments of flat or V-shaped planing surfaces to be calculated from expressions based on the projected still-water planing area.

85. Sambraus, A.: Planing-Surface Tests at Large Froude Numbers - Airfoil Comparison. NACA TM No. 848, 1938.

An attempt at verifying Wagner's theory with Sottorf's test data on flat planing surfaces was quite satisfactory for short plates at both small and large angles of attack within the entire range of Froude numbers comprising Sottorf's program. For long plates, however, the agreement was far from satisfactory and was thought to be due in part to the increasing gravity effect with plate length and also to the fact that Wagner's theory for the case of long planing surface is applicable only to infinitely small angles of attack.

Tests were made at the largest Froude number possible in order to separate the effect of gravity and finite angle of attack. Two different widths of plate were experimented upon with Froude numbers as high as 13.2 obtained with the narrowest plate and measurements were taken of wetted length, angle of attack, and resistance. The results were used to check and extend Sottorf's data.

The results were compared with those obtained by Wagner on planing theory and by Winter on airfoil theory and it was found that for short, flat planing surfaces gravity has a drag-increasing effect as was theoretically anticipated. For long, flat planing surfaces it was found that:

HYDRODYNAMICS
Sustentation - Steady Planing

(1) At large Froude numbers, the airfoil comparison retains its validity even for greater angles of attack.

(2) The lift conditions for planing surfaces of any length can be expressed by one single curve $\mu = \mu\left(\frac{t}{b}\right)$, even with finite angle of attack, where $\mu$ is the ratio of entrained water mass at finite angle of attack to that at infinitely small angles of attack and $t/b$ is the wetted length in terms of plate width times the angle of attack.

(3) Even at finite angle of attack, the reduced mass is half as great as for the airfoil.

(4) The lift conditions do not change linearly with the angle of attack.

86. Schröder, Paul: The Take-Off of Seaplanes, Based on a New Hydrodynamic Reduction Theory. NACA TM No. 621, 1931.

The planing characteristics of several models of seaplane floats and hulls at a trim of $5^{\circ}$ are analyzed in a manner analogous to the usual treatment of airfoil data. Graphs showing $\epsilon$ and $\mu$ as functions of $\beta$ (where $\epsilon$ is ratio of resistance to load, $\mu$ is a nondimensional trimming-moment coefficient, and $\beta$ is a planing coefficient corresponding to the usual aerodynamic lift coefficient) are presented to illustrate the method of analysis.

87. Shoemaker, James M.: Tank Tests of Flat and V-Bottom Planing Surfaces. NACA TN No. 509, 1934.

Four planing surfaces, all having beams of 16 inches and lengths of 60 inches but varying in dead rise by $10^{\circ}$ increments from $0^{\circ}$ to $30^{\circ}$, were tested in Langley tank no. 1. The results cover wide ranges of speeds, loads, and trims and are applicable to a variety of problems encountered in the design of seaplanes.

The data are analyzed to determine the characteristics of each surface at the trim giving minimum resistance for all the speeds and loads tested. A planing coefficient intended to facilitate the application of the results to design work is developed and curves of resistance, wetted length, and center of pressure are plotted against this coefficient. Several examples showing the application of the test data to specific design problems are included.

A theoretical solution for the wake profile produced by a flat surface during pure planing is obtained and is expressed in terms of lift, trim, and beam.

88. Sretensky, L. N.: The Theory of Hydrodynamic Gliding. R. T. P. Translation No. 1382, British Ministry of Aircraft Production. (From U.S.S.R. Acad. Sci. Bull. Dept. Tech. Sci. No. 7, 1940.)

The present paper continues an earlier report on the theory of steady gliding along the surface of a liquid of infinite depth ("On the Motion of a Glider on Deep Water"; Phys.-Mat. Bull. No. 6, 1933, U.S.S.R. Acad. Sci.). A two-dimensional solution of the theory of gliding is attempted on the assumption of infinite velocity at the leading edge of the glider.

In the first part of the paper a new derivation of the fundamental equation of the glide is given and a method of solution by Fourier series is suggested. The second part contains asymptotic equations for lift and moments, applicable for high Froude numbers. The third part contains the numerical evaluation of the equation of the glide given in the first part of the paper.

(See also abstracts 105, 106, and 174.)

Sustentation - Unsteady Planing

89. Darevsky, V. M.: Determination of the Stresses Produced by the Landing Impact in the Bulkheads of a Seaplane Bottom. NACA TM No. 1055, 1944.

The impact stresses in the bulkhead floors of a seaplane bottom are determined. The dynamic problem is solved on the assumption of a certain elastic system: the floor is assumed to be a weightless elastic beam with concentrated masses at the ends (due to the mass of the float) and with a spring that replaces the elastic action of the keel in the center. The distributed load on the floor is that due to the hydrodynamic force acting over a certain portion of the bottom. The pressure distribution over the width of the float is assumed to follow the Wagner law. The formulas given for the maximum bending moment are derived on the assumption that the keel is relatively elastic, in which case it can be shown that at each instant the maximum bending moment is at the point of juncture of the floor with the keel. The bending moment at this point is a function of $c$, which is the half-width of the wetted surface, and reaches its maximum value when $c$ is approximately equal to $b/2$, where $b$ is the half-width of the float. In general, however, the values of the bending moment at the keel for certain values of $c$ are determined and a curve is drawn. An illustrative computation is given and compared with other methods of computation.

90. Povitzky, A.: I - Impact of a Seaplane at Landing; II - Maximum Pressures on a Partly Concave Bottom of a Seaplane; III - Addendum to an Article by Wagner on the Problem of Impact and Gliding of Seaplanes. Rep. No. 199, Trans. CAHI (Moscow), 1935.

I - Theoretical calculations, based on ideal two-dimensional models of seaplane floats, are made to obtain expressions for the pressure distribution, the maximum pressure, and the resultant of the impact force. An attempt is made to improve a method previously presented in a paper by Wagner by giving a more rigorous solution of the impact problem for the cases considered. The formulas of Wagner are obtained by neglecting terms of the first order of smallness. Correction formulas for Wagner's work are found by keeping terms of the first order and neglecting those of the second. The problem is formulated more concisely by considering the spray as an integral part of the entire flow. All the magnitudes that determine this spray (thickness, velocity, kinetic energy, etc.) may be obtained by considering a single flow. The problem of landing of a seaplane with a plane bottom is solved by the method described.

II - The solution of the problem of impact on a partly concave bottom is based on the suggestion of similarity of the fluid motion due to the immersed concave bottom with the flow around two plates mutually enlarging toward one another. The rate of enlargement of these plates must be equal to the rate of enlargement of the wetted surface. With such an analogy, it is possible to obtain a comparatively simple expression for maximum pressures, which obviously arise in the center of the concave part of the bottom.

III - Methods are given for finding various important parameters occurring in Wagner's paper. These methods simplify the computations considerably and make possible the application of the Wagner method to the design of seaplane hulls.

91. Weinig, F.: Impact of a Vee-Type Seaplane on Water with Reference to Elasticity. NACA TM No. 810, 1936.

The theory developed by H. Wagner for the computation of the landing impact on water for a rigid float is extended to include elastic floats by introducing the concept of an equivalent rigid bottom to substitute for the actual elastic bottom. The effect of the elasticity on landing is found to be of minor importance. Evidence exists, however, that the elastic connection between the principal masses of the seaplane and the floats is of much greater importance than the actual elasticity of the floats. The solution of this problem is suggested.

92. Mewes, E.: The Impact on Floats or Hulls during Landing as Affected by Bottom Width. NACA TM No. 811, 1936.

Theoretical calculations are made to determine the effect on the impact force of various geometrical parameters characteristic of a seaplane float or hull. During the landing, an increase in the impact is found to occur with increase in bottom width only up to a certain limiting value of the bottom width. This limiting value both for straight and curved V-bottoms is independent of the magnitude of the angle of dead rise. In most practical cases the calculated value is smaller than the measured value.

93. von Kármán, Th.: The Impact on Seaplane Floats during Landing. NACA TN No. 321, 1929.

A simple theory is advanced to obtain, under simplifying assumptions, formulas for the impact pressure on seaplane floats and hulls. The calculations are carried out by applying the law of conservation of momentum and the principle of virtual fluid mass to the floats. It is pointed out that the method is good only when two-dimensional motion is assumed. The theoretical formula is checked with experimental evidence, and the agreement is considered satisfactory.

94. Taub, Josef: Load Assumptions for the Landing Impact of Seaplanes. NACA TM No. 643, 1931.

Theoretical formulas are presented to show that computation of the impact forces for seaplane floats and hulls should include a scale factor as well as the type of enlargement. The type of enlargement is preferably characterized by the change in surface loading. It is shown that the enlargement of a small seaplane generally results in changed float (or boat) loading as well as in changed wing loading. The theory is applied to Wagner's and Pabst's impact formulas. For evaluation, two special methods of determining the enlargement are set up as practical limits; namely, Lanchester's method, by which the surface loading is not disturbed, and Rohrbach's method, by which the loading is increased as the cube root of the enlargement factor. The results of the inquiry confirm the theory, fundamentally, and lead to some practical conclusions concerning impact, in spite of the uncertainty of individual assumptions and considerable discrepencies with existing design specifications.

95. McCaig, I. W.: Preliminary Note on the Impact of an Inclined Wedge on Water. Rep. No. H/Res/190, British M.A.E.E., April 20, 1945.

A theoretical estimation is presented of the effect of attitude and forward speed on the impact of a seaplane forebody (represented by a simple wedge) landing on calm water. An approximate formula has been obtained for the maximum impact deceleration, and a method of calculating the time to maximum deceleration is given. A numerical example is given in which the formulas are applied to a comparison of two flying boats weighing 50,000 pounds and 200,000 pounds landing at the same flight-path angle and at the same rate of descent.

HYDRODYNAMICS
Sustentation - Unsteady Planing

96. Pabst, Wilhelm: Theory of the Landing Impact of Seaplanes. NACA TM No. 580, 1930.

The theory of von Kármán is extended by considering the elasticity of the seaplane. The calculations are carried out on the basis of models represented by various masses connected by springs. Methods are discussed by means of which the spring constants may be determined experimentally.

Formulas for the impact pressure are calculated for various shapes of two-dimensional hulls, and numerical values are obtained by experimental determination of the elasticity between the fuselage and float of a Heinkel seaplane.

97. Sydow, J.: Über den Einfluss von Federung und Kielung auf den Landestoss. Jahrb. 1938 der deutschen Luftfahrtforschung, R. Oldenbourg (Munich), pp. I 329 - I 338. (Available as British Air Ministry Translation No. 861.)

The work of Pabst and Wagner, which dealt only with spring-supported, flat bases and rigid, keeled bases, is supplemented by determination of the impact force on elastic, keeled bases. The calculated results are compared with experiments.

The relationship of the keeling, the impact velocity, and the elasticity of the float support to the landing impact of a seaplane has been investigated by calculation and experiment, for the case of floats with straight, keeled bases. For the cases tested by experiment, the agreement between experimental and calculated results is good.

Application of the results must be undertaken with great care because little is known with regard to the particular elastic properties of the airplane that are important for this problem, and no accurate data are available for the impact length and impact velocity, which depend not only on the airplane but also on the seaway.

(See also abstracts 221 and 226.)

HYDRODYNAMICS
Sustentation - Hydrofoils

98. Schmieden, C.: Die Berechnung kavitationssicherer Tragflügelprofile. Z.f.a.M.M., Bd. 12, Heft 5, Oct. 1932, pp. 288-310.

With the assumption that potential theory may be applied, a method has been developed that may be used to calculate section profiles which have superior cavitation characteristics. The theory is sufficiently general to give the pressure distribution and the lift for a given profile. The method is applied to a number of specific examples, and the results of the sample calculations are given in detail.

99. Land, Norman S.: Characteristics of an NACA 66,S-209 Section Hydrofoil at Several Depths. NACA CB No. 3E27, 1943.

A hydrofoil section, designated NACA 66,S-209, has been developed especially for use in high-speed underwater operation. The section has a sharp leading edge and a substantially flat chordwise pressure distribution at a lift coefficient of 0.2.

Lift, drag, angle of attack, and speed were measured at different depths of submersion varying from $\frac{1}{2}$ chord to 5 chords and plotted in conventional NACA aerodynamic form. These curves show that the lift coefficient increases directly with the angle of attack. The drag is approximately constant up to $2^{\circ}$ and then increases sharply for higher angles of attack; a maximum L/D value is thus obtained. It was found that this ratio (about 27 for speeds of 45 fps) decreased with an increase in speed. The lowest speed at which cavitation was observed on the upper surface of the hydrofoil at each angle of attack is indicated.

100. Betz, A.: Einfluss der Kavitation auf die Leistung von Schiffsschrauben. Sonderdruck der Verhandlungen des III Internationalen Kongresses für technische Mechanik (Stockholm), 1931.

An approximate theory of hydrofoils operating at high velocities is developed on the assumption that the flow around a fully cavitating hydrofoil is analogous to the flow about a flat plate. Equations are derived which give the lift coefficient $C_L$ and drag coefficient $C_D$

HYDRODYNAMICS
Sustentation - Hydrofoils

as functions of angle of attack $\alpha$ and cavitation number. The theory as given applies only if the pressure side of the hydrofoil section is flat and if cavitation is developed only on the suction side. Furthermore, only small angles of attack may be considered. [The formulas have been checked at Göttingen by O. Walchner whose experiments confirm the analytical expressions.]

According to Betz's theory, the shape of the suction side of the hydrofoil is immaterial with regard to the value of the lift and drag coefficients. This conclusion appears to be justified only insofar as the lift coefficient is concerned. [On the other hand, neither NACA's nor Walchner's experiments appear to have drag coefficients independent of profile thickness.]

With the theory, lift and drag coefficients are predicted only for cavitation numbers corresponding to fully developed suction-side cavitation. Moreover, the same coefficients are known theoretically for the case in which no cavitation occurs at all ($C_L = 2\pi\alpha$). No work has been done on the intermediate region of partially developed cavitation, as the physical processes are not well understood in that region. [Later experiments seem to indicate that for increasing cavitation numbers both the lift and drag coefficients at first follow Betz's formula well then reach a maximum peak in the region of partially developed cavitation, beyond which they approach a constant value given by the formulas for the undisturbed flow. This latter value is in all instances somewhat below the highest lift and drag developed.] The theory has been applied to calculate the efficiency of ship propellers as a function of the lift-drag ratio and the degree of cavitation existing on the propeller blades.

101. Knapp, Robert T., and Daily, James W.: Force and Cavitation Characteristics of the NACA 4412 Hydrofoil. NDRC, div. 6, sec. 6.1, OSRD, CIT, June 10, 1944.

This report covers water-tunnel tests of a "two-dimensional" installation of a 3-inch-chord, 10-inch-span section of the NACA 4412 profile. The tests included measurements during cavitation-free operation of the hydrodynamic forces and moments as functions of the angle of attack and velocity of flow and observations under cavitating conditions of the inception and growth of cavitation for different angles of attack as functions of the cavitation parameter K. The results are compared with existing information on this hydrofoil from other sources and the water-tunnel test methods for obtaining the hydrodynamic characteristics of hydrofoils are discussed. The main findings are as follows:

1. Water-tunnel testing provides a very satisfactory method of observing and measuring cavitation characteristics of hydrofoils as well as non-cavitating characteristics, all with a single test installation.

2. Photographs of cavitation and the simultaneous pressure and velocity measurements illustrate:

   (a) The acceleration of inception of cavitation by increase in velocity or by decrease in pressure (either one of which causes the cavitation parameter K to become smaller) and by increase in angle of attack. The results are summarized conveniently in the form of curves of submergence required to avoid cavitation for different velocities and attack angles.

   (b) The inception, first on one face and then on the other face of the hydrofoil, as the cavitation parameter is reduced.

   (c) The change in magnitude and the character of the cavitation bubble with angle of attack and with cavitation parameter.

   (d) The effect of small surface irregularities or adhesion of foreign material to the leading edge of the hydrofoil in accelerating inception of cavitation.

3. With the "two-dimensional" test installations the infinite aspect ratio or "section" characteristics can be approximated without data correction of any kind. This is in contrast with the normal type of installation with three-dimensional flow about short spans which requires elaborate corrections to obtain infinite aspect ratio characteristics.

HYDRODYNAMICS
Sustentation - Hydrofoils

4. Evaluation of possible errors indicates that the accuracy of these data is good in the low-lift range of normal hydrofoil applications. At high lifts (large angles of attack) the absolute accuracy is reduced but the good comparative results are still obtained.

102. Benson, James M., and Land, Norman S.: An Investigation of Hydrofoils in the NACA Tank. I - Effect of Dihedral and Depth of Submersion. NACA ACR, Sept. 1942.

Tests have been made at Langley tank no. 1 on a series of hydrofoils to obtain quantitative information on the lift-drag ratio of hydrofoils as a function of the particular shape used, the velocity, the angle of dihedral, and the depth of submersion. The hydrofoils tested included the NACA 16-509 airfoil section and a section derived from the 16-509 airfoil by sharpening the leading edge. Velocities attained were as high as 95 feet per second, and the angle of dihedral was varied to include 0°, 10°, 20°, and 30°.

At a depth greater than 4 or 5 chords, the presence of the free water surface did not affect the lift and drag. As the hydrofoil approached the surface, lift and drag decreased and the speed at which cavitation first appeared (this point was noted on the curves) was increased. At very shallow immersions ($\frac{1}{2}$ chord and less), lift and drag became discontinuous when separation occurred over the hydrofoil. For this reason, the use of large angles of dihedral was found to be advantageous.

A maximum loading of the hydrofoil was defined by speed for complete upper-surface cavitation; this maximum load was about 2200 pound-feet. For high speeds and low angles of attack, furthermore, a loss of lift occurred that was attributed to lower-surface cavitation.

103. Numachi, F.: Measurement of Forces on Slotted Blade Profiles under Cavitation. R.T.P. Translation No. 1464, British Ministry of Aircraft Production. (From Werft Reederei Hafen, Jahrg. 20, Oct. 15, 1941, pp. 295-299.)

Since wind-tunnel tests have shown that higher lift coefficients are attainable with slotted profiles, information on the characteristics

HYDRODYNAMICS
Sustentation - Hydrofoils

of slotted blades under cavitation was desired. The results of tests showed that slotted blades directly cause cavitation and produce characteristics almost opposite to those anticipated by the author and to those generally required. The slotted profiles tested were also inferior to the original Clark Y profile with respect to the degree of variation in angle of attack for minimum gliding coefficient.

104. Coombes, L. P., and Davies, E. T. J.: Note on the Possibility of Fitting Hydrofoils to a Flying Boat Hull. Rep. No. B.A. 1440, British R.A.E., Nov. 1937.

The present state of knowledge with regard to hydrofoils is very briefly reviewed. On the basis of the assumption that no cavitation will occur over the entire range of operating speeds (0-113 fps) and that the lift-drag ratio remains constant while the hydrofoil is submerged, a theoretical analysis is made of the efficiency of a planing surface fitted with a hydrofoil, and the results are used to find the reduction in drag which would result from fitting a flying-boat hull with a hydrofoil. As a reduction of some 20 percent in the hump drag is indicated, it is concluded that the results of the analysis are sufficiently promising to justify further experimental work, and the lines on which it should be done are suggested.

105. Weinig, F.: On the Theory of Hydrofoils and Planing Surfaces. NACA TM No. 845, 1938.

The hydrodynamic properties of hydrofoils and planing surfaces have been investigated under the assumption that airfoil theory is applicable if the free water surface is introduced as an additional boundary condition.

The problem of the hydrofoil has therefore been studied in two dimensions by investigating the influence of the free water surface on a corresponding airfoil; lift and drag coefficients have been computed as a function of depth of submersion. The planing problem has been considered and the fundamental characteristics have been calculated on the original supposition. Methods similar to those used in airfoil theory may be applied for the calculation of pressure distributions.

HYDRODYNAMICS
Sustentation - Hydrofoils

The hydrofoil problem has been treated also in three dimensions on the basis of an analogy to the nonstaggered biplane problem. Lift and drag coefficients have been deduced for deep and shallow submersions. For the case where the hydrofoil tips penetrate the free water surface, lift and drag have been computed on the basis of the boxplane analogy.

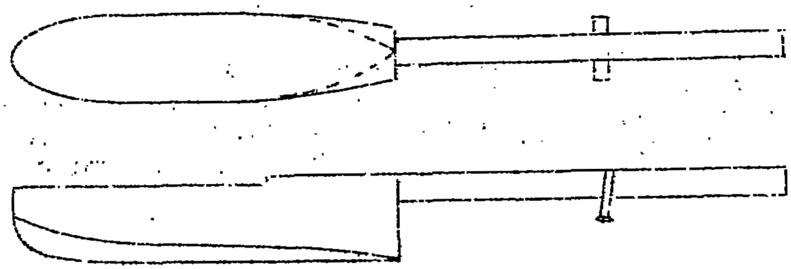
The planing problem in three dimensions has been established and discussed briefly with suggestions as to a method for its solution.

The influence of cavitation on the lift of the hydrofoil has been noted, and an attempt has been made to compute a shape with a favorable pressure distribution that delays the onset of cavitation.

The effect of gravity on the resistance of hydrofoils and planing surfaces has been studied on the basis of Wagner's results. It is concluded that the influence of gravity may be neglected in both cases.

106. Wadlin, Kenneth L.: Preliminary Tank Experiments with a Hydrofoil on a Planing-Tail Seaplane Hull. NACA RB No. L4C28, 1944.

Exploratory tests were made to determine the feasibility of using a hull with a form similar to that shown in the accompanying diagram to perform the functions of a conventional flying-boat hull and to give some improvements in the hydrodynamic resistance and stability characteristics. The possibility of using a hydrofoil on the afterbody of this type of hull to furnish hydrodynamic lift is explored. It is shown that an afterbody of very small cross section and having no chines can supply sufficient lift to be successfully used on a flying-boat hull. A single hydrofoil can be added to an afterbody of this type in such a manner that it will provide additional hydrodynamic lift without introducing instability. Although this additional lift would slightly reduce the load on the afterbody boom and, consequently, would reduce the height of the spray around the tail, it is doubtful that these benefits would be sufficient to warrant the use of a hydrofoil in such a manner.



HYDRODYNAMICS
Sustentation - Hydrofoils

107. King, Douglas A.: Preliminary Tank Tests of an Outboard Float Having the Form of a Streamline Body of Revolution Fitted with a Hydrofoil. NACA ACR No. L4D06, 1944.

Preliminary tests were made in Langley tank no. 1 to investigate the hydrodynamic qualities of a streamline body of revolution of a fineness ratio of 5.14, both alone and with a lifting hydrofoil. The hydrofoil, supported below the body by means of struts that gave the effect of end plates at the tips of the hydrofoil, had a chord about 48 percent of the maximum diameter of the body, an aspect ratio of 1.92, and a dihedral angle of 30°.

In general, at constant drafts, the lift of the streamline body without the hydrofoil decreased with increasing speed. When the trim of the body was 5° and the body was not wholly submerged for any two values of draft, the speed at which the lift became negative was greater for the greater draft than for the lesser. When the trim of the body was increased to 10° and the body was completely submerged, the lift did not vary greatly with speed. The resistance of the body in this condition was of the same order of magnitude as the lift. At high trims the hydrodynamic lift-resistance ratios of the streamline body with the hydrofoil were higher than those of a conventional outboard float.

The aerodynamic drag of the combination of streamline body and hydrofoil was computed and compared with that of several conventional floats. The minimum drag of the combination was about 50 percent of the average minimum drag of the conventional floats. The combination at an angle of attack of 0° and an angle of incidence of the hydrofoil of 10° had a drag about 50 percent of the average drag of the conventional floats at an angle of attack of 0° based on the keel just forward of the step and about 35 percent of the average drag of the conventional floats at an angle of attack of 5°.

108. Ward, Kenneth E., and Land, Norman S.: Preliminary Tests in the NACA Tank to Investigate the Fundamental Characteristics of Hydrofoils. NACA ACR, Sept. 1940.

The present preliminary investigation was made to study the hydrodynamic properties and general behavior of simple hydrofoils. Six 5- by 30-inch plain, rectangular hydrofoils were tested in Langley tank no. 1 at various speeds, angles of attack, and depths below the

HYDRODYNAMICS
Sustentation - Hydrofoils

water surface. Two of the hydrofoils had sections representing the sections of commonly used airfoils, one had a section similar to one developed by Guidoni for use with hydrofoil-equipped seaplane floats, and three had sections designed to have constant chordwise pressure distributions at given values of the lift coefficient for the purpose of delaying the speed at which cavitation begins.

The experimental results are presented as curves of the lift and drag coefficients plotted against speed for the various angles of attack and depths for which the hydrofoils were tested. A number of derived curves are included for the purpose of better comparing the characteristics of the hydrofoils and to show the effects of depth. Several representative photographs show the development of cavitation on the upper surface of the hydrofoils.

The results indicate that properly designed hydrofoil sections will have excellent characteristics and that the speed at which cavitation occurs may be delayed to an appreciable extent by the use of suitable sections.

109. Benson, James M., and King, Douglas A.: Preliminary Tests to Determine the Dynamic Stability Characteristics of Various Hydrofoil Systems for Seaplanes and Surface Boats. NACA RB No. 3K02, 1943.

Qualitative tests were performed at the Langley tanks to determine the stability characteristics of several arrangements of hydrofoils that have been proposed for use on seaplanes and high-speed surface boats of the PT class. For this purpose the hydrofoils were mounted on a $\frac{1}{27}$-size model of a hypothetical 75-foot PT boat having a displacement of 160,000 pounds with the exception of the Guidoni S.V.A.-type hydrofoils, which were mounted on a streamline spindle.

The stability of the hydrofoils was tested in six different arrangements: (a) two flat hydrofoils in tandem, (b) two V-hydrofoils in tandem, (c) two curved hydrofoils in tandem, (d) a monoplane hydrofoil with tail plane (Tietjens hydrofoil system), (e) a flat hydrofoil ladder, and (f) an arrangement similar to that used by Guidoni. In the series of tests, models were towed either by using a staff or a line; several arrangements, in addition, were tested by

HYDRODYNAMICS
Sustentation - Hydrofoils

using self-propelled models entirely free from the towing carriage. Yawing and porpoising instability were noted.

The results, although obtained under conditions in which cavitation did not occur, indicated that the most important effect involved is the erratic change in lift and drag that occurs as a hydrofoil approaches the free surface of the water. This effect is more severe for a flat horizontal hydrofoil than for one having dihedral. The effect is also more severe for monoplane hydrofoils than for multiplane hydrofoils.

A ladder-like arrangement of several hydrofoils, inclined at a dihedral angle of about 20° from the horizontal and arranged in a tripodal system on a self-propelled model, was found to be relatively free from instabilities exhibited by monoplane systems. An arrangement of two ladder-like systems in tandem on a streamline spindle was found to be stable throughout a wide range of speeds. No dynamic instability was observed when this model (representing the hull of a flying boat) was lifted out of the water to simulate take-off.

It is believed that more extensive studies of a quantitative nature should be undertaken under conditions more nearly approximating full-size condition, in which cavitation is probably a very important consideration.

110. Land, Norman S.: Preliminary Tests to Investigate Low-Speed Spray of a 1/8-Full-Size Dynamic Model of the PB2Y-3 with a Hydrofoil - NACA Model 131-X. NACA MR, Bur. Aero., Aug. 25, 1943.

Tests were conducted at Langley tank no. 1 to investigate the effectiveness of hydrofoils in eliminating spray entering the propellers of a flying boat. The purpose of attaching hydrofoils was to provide additional lift, thus unloading and trimming the hull at low speeds.

The hydrofoil used in the tests had an NACA 16-1009 airfoil section and the struts, a double convex circular arc section with a fineness ratio of 11.2. The model was a $\frac{1}{8}$-size dynamically similar model of the PB2Y-3 airplane with gross load of 148 pounds (76,000 lb full size), flaps deflected 40°, elevators neutral, and propellers

HYDRODYNAMICS
Sustentation - Hydrofoils

operating at 6200 rpm. These conditions simulated to scale the full-size airplane. Short, accelerated runs were made through the speed range in which bow spray was objectionable.

The tests indicated that none of the hydrofoil arrangements used completely eliminated spray entering the propeller disks. All positions, however, except the one in which the hydrofoil was placed most aft, greatly reduced the volume and duration of the spray. This reduction was believed to be caused by the additional lift and consequent decreased draft of the hull at the critical speeds.

Monoplane hydrofoils, like the one tested, cause violent instability when the tips break through the water surface. It is therefore necessary to use a closely controlled retracting device that will raise the hydrofoils as soon as the critical spray speeds have been exceeded.

111. Walchner, O.: Profile Measurements during Cavitation. NACA TM No. 1060, 1944.

Measurements were made at the Kaiser Wilhelm Institute for Flow Research at Göttingen to determine the forces acting on hydrofoils during cavitation. For this purpose a hydrofoil of circular arc section was mounted into a ring channel through which a steady motion of water could be sustained by means of a pump. By controlling the rate of flow through the test section and the pressure in the surge tank, any desired cavitation number could be obtained even at low speeds. Forces on the hydrofoil were measured with a balance directly placed in the channel and precautions were taken to account for additional forces due to the geometry of the balance.

During the experiments three different types of cavitation were observed: (1) cavitation on the front edge of the suction side of the hydrofoil, (2) cavitation beyond the middle of the suction side of the hydrofoil, and (3) cavitation at the front edge of the pressure side of the hydrofoil. The results were given in terms of the cavitation number $\left(\text{defined as } \frac{p - p_D}{q}\right.$ where $p$ was the pressure of undisturbed flow, $p_D$ was the vapor pressure, and $q$ was the dynamic pressure$\left.\right)$ and the lift and drag coefficients.

HYDRODYNAMICS
Sustentation - Hydrofoils

For given trim of the hydrofoil the three different regions at which cavitation occurs interchanged as the cavitation number was altered. Lift and drag coefficients when plotted against each other with trim as a parameter show that the profile of the hydrofoil becomes effectively less suitable because of cavitation at low lift coefficients. When cavitation occurs in accordance with case (1), small increases in the lift-drag ratio are obtained. As the region of cavitation moves backward, the profile of the hydrofoil becomes less efficient and when case (2) is reached, the lift-drag ratio is at a minimum. Case (3) is similar to case (1).

The results obtained were compared with the theory of Betz, which gives for the lift coefficient the formula

$$C_L = \frac{\pi}{2}\alpha + \frac{p - p_D}{q}$$

where $\alpha$ is the angle of attack. This theory is only applicable when cavitation occurs in accordance with case (1). In this instance the agreement between theory and experiment was found to be good.

112. Thornburg, F. L.: Report on the Use of Hydrofoils to Assist the Take-Off of the PB2Y-3 Airplane. Rep. No. ZH-29-013, Consolidated Aircraft Corp., 1943.

A brief study has been made of hydrofoil assistance during the critical spray period of take-off for the PB2Y-3 airplane. Three systems of monoplane hydrofoils were investigated: (1) with one supporting hydrofoil just aft of the center of gravity, (2) with main supporting hydrofoil forward and a trimming hydrofoil aft of the center of gravity, and (3) with main supporting hydrofoil aft and a trimming hydrofoil forward of the center of gravity.

The results of these studies indicate that the use of hydrofoils will increase the acceleration of the airplane and will decrease the draft at speeds up to 70 feet per second. The use of hydrofoils will lower the take-off time with normal gross load about 14 to 15 seconds and should improve the spray. The hydrofoils must be retracted at around 60 feet per second to avoid cavitation, which begins at or below this speed at almost all trims.

HYDRODYNAMICS
Sustentation - Hydrofoils

113. Baldwin, Casey: Seaplanes and Hydrofoils. Canadian Aviation, Jan. 1945, pp. 48-50.

The advantages of the seaplane over the landplane may be given as follows:

1. Greater pay load

2. Greater safety in water take-off and landing

3. Safety with overloading

4. No expense or weight of retractable landing gear

5. Better stability and seaworthiness and simpler construction with increased size

6. Greater safety in crash landing

7. Greater safety in rocket assistance

At low speeds, hydrofoils are at least as efficient as the best airfoils, have a high aspect ratio, and are arranged in steps with ample gap-chord ratio and with whatever dihedral angle is deemed advisable. The dihedral, besides adding to the stability and general seaworthiness, provides smooth reefing action, resulting in an almost flat resistance curve.

The principle involved in hydrofoil craft is that of the differentiation of functions, the hull for flotation and housing only, the wings for air support, and hydrofoils for dynamic water support and cushioning the shock of coming down on the water. Penetration of the bottom hydrofoils and their small size prevents porpoising and bouncing, whether in taking off or coming down in rough water.

114. Guidoni, A.: Seaplanes - Fifteen Years of Naval Aviation. Jour. R.A.S., vol. XXXII, no. 205, Jan. 1928, pp. 25-64.

The history of float seaplanes equipped with hydrofoils is traced through the years 1910 to 1925. Information regarding the design of seaplane floats and the effects of hydrofoils on the performance is given in terms of lift and drag.

HYDRODYNAMICS
Sustentation - Hydrofoils

The chief advantages of hydrofoils lie in: (1) weight economy; (2) the possibility of designing seaplane floats to give good aerodynamic characteristics, thus reducing a common source of air drag; (3) improved take-off and landing characteristics, especially in rough water; and (4) reduced water resistance.

Hydrofoils extend below the bottom of the boat and may become fouled by debris. The hydrofoils must be carefully designed structurally to prevent breaking at high speeds. Special care must be given to the choice of hydrofoil section and angle of attack of the lower hydrofoils to maintain high efficiency.

115. Grunberg, V.: La sustentation hydrodynamique par ailettes immergées. Essais d'un système sustentateur autostable. L'Aérotechnique, no. 174, 16e année, supp. to L'Aéronautique, no. 217, June 1937, pp. 61-69.

The system tested consisted of a hull with a hydrofoil at the stern and a float (or a series of floats) at the bow. The center of gravity was located so that 80 to 92 percent of the load was carried by the hydrofoil.

At high speeds the forward floats planed. The hydrofoil lifted the hull and the model pivoted about the forward floats, so that the angle of attack of the hydrofoil was reduced as the speed increased.

Adaptations to aircraft are discussed and tests of a model on a whirling arm are described. The load-resistance ratio $\Delta/R$ of the model varied between 3 and 6 at planing speeds and was stated to be higher than for planing craft.

116. Land, Norman S.: Tank Tests of a Grunberg Type High-Speed Boat with a Lifting Hydrofoil and Planing Surface Stabilizers. NACA Models 103-A and 103-B. NACA MR, Bur. Aero., July 22, 1940.

Tank tests were made to determine the suitability of a Grunberg type high-speed boat for use in open-water towing of Langley tank models. The Grunberg type motorboat employs a hydrofoil under the hull as a lifting device and two planing surfaces forward of the hull

HYDRODYNAMICS
Sustentation - Hydrofoils

as stabilizers. Test results were compared with the results of a test of the hull alone made previously. The results showed that the Grunberg hydrofoil boat has considerable merit as a high-speed boat and that the top speed of an existing boat could be considerably raised by modification to a Grunberg type.

117. Land, Norman S.: Tank Tests of a Guidoni Type SVA Seaplane Float with Hydrofoils - NACA Models 67, 67A, 67B, and 67C. NACA MR, Bur. Aero., Sept. 1, 1942.

Investigations were made at Langley tank no. 1 of the properties of a seaplane float of the original Guidoni type with different arrangements of the hydrofoils. The original model was an approximate half-size reproduction of a float used by A. Guidoni on his SVA seaplane. Three modifications of the original model were also tested; the first two sets were multiplane arrangements following Guidoni's descriptions and the third was a monoplane set.

The tests were conducted with the model free to trim at several positions of the center of gravity. Results were plotted in terms of resistance, trim, rise, load on the water, and load-resistance ratio against speed. It was noted that all the models passed through regions of longitudinal instability. The front hydrofoils lifted first, causing an increase in the angle of attack and an increase in lift. Because of the large moment of inertia of the model, the bow rose beyond the equilibrium point thus becoming unstable. A further cause for this instability was the production of cavitation as the hydrofoils neared the water surface.

It is believed that the tests were not indicative of the actual full-size instability because of the excessive moment of inertia of the model.

118. King, Douglas A.: Tank Tests of a Model of the PBY-Type Outboard Float with Hydrofoils. NACA MR, Bur. Aero., Dec. 16, 1943.

Tests were made in Langley tank no. 1 with a $\frac{1}{5}$-size model of a PBY-type outboard float, which was fitted with various arrangements of hydrofoils for the purpose of increasing the hydrodynamic lift.

HYDRODYNAMICS
Sustentation - Hydrofoils

All of the configurations tested increased the hydrodynamic lift, some by as much as 100 percent. The resistance was also increased so that the lift-resistance ratio was not greatly altered, especially when the draft of the float was great enough for the hydrodynamic forces on the float itself to be large.

A hydrofoil supported below the float by means of struts, which gave the effect of end plates at the tips of the hydrofoil, developed about 20 percent more lift than and about the same lift-resistance ratio as hydrofoils of twice the total area projecting from the sides of the float at the chines. Both hydrofoils had chords of about 50 percent of the maximum beam of the float. When the hydrofoil was supported below the float on struts, an increase in the distance of the hydrofoil below the float from $\frac{1}{2}$ chord to $1\frac{1}{2}$ chords resulted in increases in lift and resistance of about 30 percent.

119. Land, Norman S., Lina, Lindsay J., and Havens, Robert F.: Tank Tests of Two Ogival-Section Hydrofoils. NACA MR, Bur. Ships, April 16, 1942.

Tests made at the Langley tanks to determine the characteristics of hydrofoils of various sections have proved to be of considerable interest in the design of blades of ship propellers. Tests have been made of two hydrofoils of plano-convex (ogival) section with $2\frac{1}{2}$- and $6\frac{2}{3}$-percent chord thickness.

Curves are presented showing the variation with speed of the lift and drag coefficients of these ogival hydrofoils with angle of attack as a parameter. Summary curves of the characteristics of each section (lift and drag coefficient, lift-drag ratio, and cavitation speed as a function of angle of attack) are also given.

120. Llewelyn-Davies, D. I. T. P.: Tank Tests on a Streamlined Wing Tip Float with a Hydrofoil Attached. Rep. No. Aero 1910, British R.A.E., Feb. 1944.

Tank tests were required to investigate the possibility of using as a wing-tip float a streamlined body with a hydrofoil

HYDRODYNAMICS
Sustentation - Hydrofoils

attached. Tests were made on an airship-shaped float with a hydrofoil attached in various positions and incidences. The effects of several modifications were noted and observations were made of the draft, resistance, and water flow.

The modification with a ventilated step at the maximum thickness was found to have a water performance about equal to that of the Sunderland wing-tip float although the change in draft due to load was greater. The tendency for the float to porpoise at speeds between 25 and 40 knots would probably restrict its use on seaplanes. The reduction in air drag on a 5000-pound float was estimated to be about $1\frac{3}{4}$ pounds at 100 feet per second or a reduction of about 35 percent of the air drag of the wing-tip floats.

(See also abstracts 1 and 192.)

Steady Longitudinal Forces and Moments

121. Parkinson, John B., Olson, Roland E., Draley, Eugene C., and Luoma, Arvo A.: Aerodynamic and Hydrodynamic Tests of a Family of Models of Flying-Boat Hulls Derived from a Streamline Body - NACA Model 84 Series. NACA ARR No. 3I15, 1943.

A series of related forms of flying-boat hulls representing various degrees of compromise between aerodynamic and hydrodynamic requirements was tested in Langley tank no. 1 and in the Langley 8-foot high-speed tunnel. The purpose of the investigation was to provide information regarding the penalties in water performance resulting from further aerodynamic refinement and, as a corollary, to provide information regarding the penalties in range or pay load resulting from the retention of certain desirable hydrodynamic characteristics. The information should form a basis for over-all improvements in hull form.

The related models of the series were based on an arbitrary streamline body of revolution. The variations in form were developed

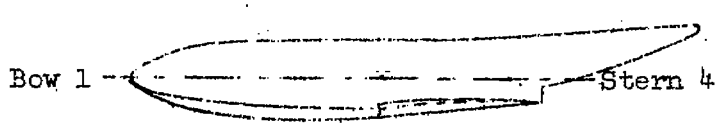
HYDRODYNAMICS
Steady Longitudinal Forces and Moments

in such a way as to show clearly the effect of conventional departures from the ideal streamline body made in the design of flying-boat hulls.

The models were 114.85 inches long and the diameter of the basic streamline form was 15.92 inches. In the hydrodynamic tests, resistance and trim and trimming moments were measured at all speeds and loads of interest and the spray patterns were photographed. In the aerodynamic tests, lift, drag, and pitching moment were measured with transition fixed at 5 percent of the length at speeds up to 420 miles per hour and at Reynolds numbers up to 30,000,000.

The results of general free-to-trim and fixed-trim tests of a model incorporating the most promising of the forms tested are presented in the form of design charts for estimating static water lines and take-off performance. The aerodynamic data, because of their unique character, are presented for use in estimating the effect of the variables investigated on aerodynamic performance.

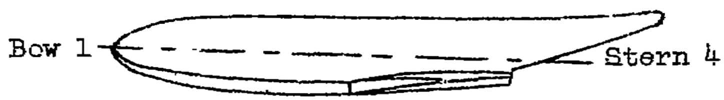
It is concluded that the aerodynamic drag of a planing type of hull need not be more than 25 percent greater than that of the streamline body from which it is derived. This difference might be reduced by the development of a form of afterbody that has less influence on the flow than does the conventional pointed type.




(1) Effect of addition of chine flare

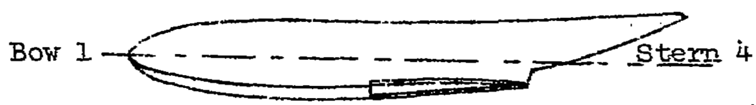
Chine flare has a small effect on the resistance and trim up to and including the hump but results in a much "cleaner" running hull. Chine flare on the afterbody reduces the resistance at the hump and slightly increases the resistance at planing speeds.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments



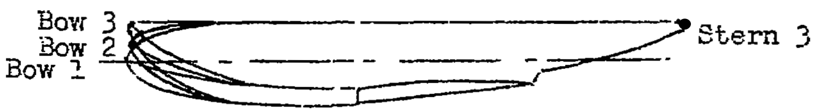

(2) Effect of increasing angle of afterbody keel

Increasing the angle of afterbody keel increases the trim and resistance at the hump and lowers the resistance at planing speeds. A low afterbody results in the cleanest running at low speeds but allows instability to occur at a lower angle at planing speeds.




(3) Effect of increasing depth of step

Increasing the depth of step has a small effect on resistance and spray at low speeds, decreases resistance at planing speeds, improves the high angle stability, and slightly increases the air drag.

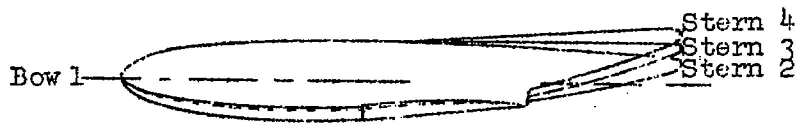



(4) Effect of increasing height of bow

Increasing the height of the bow decreases the trim, increases the resistance at low speeds, results in a "dirtier" hull, and has a small adverse effect on the air drag.

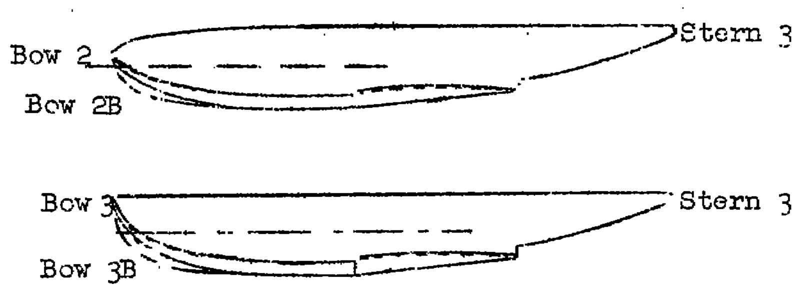
[redacted]

HYDRODYNAMICS
Steady Longitudinal Forces and Moments




(5) Effect of increasing height of stern

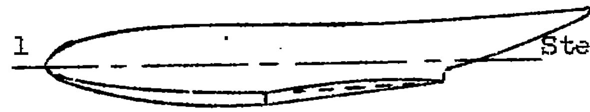
Increasing the height of the stern increases resistance and trim at speeds below the hump, decreases the hump speed, and does not affect the value of the maximum resistance at the hump. A low stern runs awash and requires a higher position of the tail surfaces. Increasing the height of the stern has a large adverse effect on air drag.




(6) Effect of increasing angle of dead rise at bow

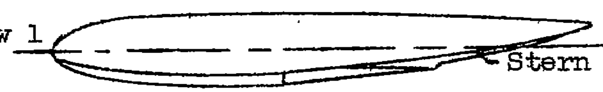
Increasing the angle of dead rise by dropping the keel line reduces the low-speed resistance slightly, results in a large improvement in cleanness of running, and has little effect on the air drag.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments



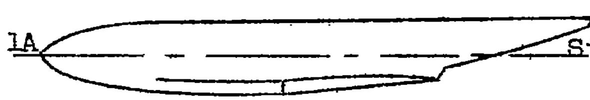

(7) Effect of decreasing angle of dead rise on afterbody

Decreasing the angle of dead rise on the afterbody decreases the trim and resistance at speeds up to and including the hump and tends to increase the clearance of the tail extension.




(8) Effect of addition of third planing surface

The addition of a third planing surface has a negligible effect on the trim and resistance and somewhat reduces the wetting of the stern.




(9) Effect of rounding chines at bow

Rounding the chines at the bow results in very poor spray characteristics in smooth water and probably would be impracticable in rough water.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

122. Truscott, Starr, and Dawson, John R.: A Comparison of the Results from General Tank Tests of 1/6- and 1/12-Full-Size Models of the British Singapore IIC Flying Boat. NACA TN No. 858, 1942.

A $\frac{1}{6}$-size resistance model of the hull of the British Singapore IIC flying boat was tested in Langley tank no. 1. The results are given in the form of charts and are compared with the results of previous tests made of a $\frac{1}{12}$-size model in Langley tank no. 1 (abstract 150) and with the results of tests made of another $\frac{1}{6}$-size model of the same hull in the tank of the Royal Aircraft Establishment.

When the data from the tests of the $\frac{1}{6}$- and $\frac{1}{12}$-size models were compared on the basis of the Froude law of comparison, differences were found. This fact supported the belief that the small scale of the model and the use of a model that was too small to suit the equipment of Langley tank no. 1 had caused the results of the tests of the $\frac{1}{12}$-size model to be less reliable than the results of the tests of the $\frac{1}{6}$-size model. The results of the tests of the two models agreed sufficiently well to show that tests of a small model, if made meticulously and with suitable equipment, may give usable results, but that a larger model should be used whenever feasible.

The results of the NACA tests of the $\frac{1}{6}$-size model were found to be in good agreement with the R.A.E. tests of a model of the same size.

123. Shoemaker, James M.: A Complete Tank Test of a Flying-Boat Hull with a Pointed Step - N.A.C.A. Model No. 22. NACA TN No. 488, 1934.

When a conventional hull is planing at high speeds, considerable resistance is caused by the forebody wake that hits the afterbody. It was believed that if a hull were designed with a low dead rise,

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

pointed step, and depth of step great enough to prevent the wake of the forebody from impinging on the afterbody at high planing speeds, the resistance and hence the take-off time and distance would be considerably reduced. It was thought that the air drag of a deep pointed step, with the chines fair in plan form, would be no worse than that of a conventional transverse step. NACA model 22 was tested by the "general" resistance method. A take-off calculation was made and the results were compared with those of NACA model 11-A, a fair representative of well-designed hulls of the conventional American type.

The results of the tests show that low resistance at high speeds and light loads has been realized. The relatively high hump resistance of model 22 does not appear to be inherent in the deep pointed step but seems rather to be caused by the upward curvature of the buttocks toward the bow. The low-speed spray characteristics were observed and it was found that the bow blister is heavy and rises to a considerable height, probably also because of the upward curvature of the buttocks near the bow. At high speeds and low angles the model is very clean from spray and runs only on the forebody with the spray entirely clearing the afterbody.

124. Shoemaker, James M., and Parkinson, John B.: A Complete Tank Test of a Model of a Flying-Boat Hull - N.A.C.A. Model No. 11. NACA TN No. 464, 1933.

The limitations of the conventional tank test of a seaplane model are discussed. The advantages of a complete test, giving the characteristics of the model at all speeds, loads, and trims in the useful range, are pointed out.

The data on NACA model 11, obtained from a complete test, are presented and discussed. The results are analyzed to determine the best trim for each speed and load. The data for the best trim condition are reduced to nondimensional form for ease of comparison and application.

A practical problem using the characteristics of model 11 is presented to show the method of calculating the take-off time and run of a seaplane from these data.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

125. Parkinson, John B.: A Complete Tank Test of a Model of a Flying-Boat Hull - N.A.C.A. Model No. 11-A. NACA TN No. 470, 1933.

NACA model 11-A was designed as an improvement over NACA model 11, a complete test of which is described in abstract 124. In contrast with the longitudinal upward curvature in the planing bottom forward of the main step on model 11, the planing bottom of model 11-A was made as flat as practicable. Otherwise, the two models had very nearly the same form.

The results of towing tests of model 11-A in Langley tank no. 1 over wide ranges of speed, load on the water, and trim are presented, both as original test data and as nondimensional coefficients. A comparison is made with similar results from the test of model 11. The practical significance of the improvement obtained is demonstrated by applying the data from the new form to the illustrative design problem used in the note on model 11.

126. Shoemaker, James M.: A Complete Tank Test of a Model of a Flying-Boat Hull - N.A.C.A. Model 16. NACA TN No. 471, 1933.

A model of a two-step flying-boat hull, of the type generally used in England, was tested according to the complete method described in abstract 124. The lines of this model were taken from offsets given by Mr. William Munro in "Flight," May 29, 1931. The data cover the ranges of load, speed, and trim that may be of use in applying the hull form to the design of any seaplane. The results are reduced to nondimensional form to aid application to design problems and to facilitate comparison with the performance of other hulls.

The water characteristics of NACA model 16 are compared with those of NACA model 11-A, which is representative of current American practice. The results show that, when the two forms are applied to a given seaplane design under optimum conditions for each, the performance of model 16 will be somewhat inferior to that of model 11-A.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

127. Dawson, John R.: A Complete Tank Test of the Hull of the Sikorsky S-40 Flying Boat - American Clipper Class. NACA TN No. 512, 1934.

The results of a complete test in Langley tank no. 1 of a model of the Sikorsky S-40 flying-boat hull (American Clipper) are reported. The test data are given in tables and curves. From these data non-dimensional coefficients are derived for use in take-off calculations, and the take-off time and run for the S-40 are computed. The computed take-off time is found to agree substantially with the take-off time obtained by the Sikorsky Aviation Corporation in performance tests of the actual craft.

128. Shoemaker, James M., and Bell, Joe W.: Complete Tank Tests of Two Flying-Boat Hulls with Pointed Steps - N.A.C.A. Models 22-A and 35. NACA TN No. 504, 1934.

The results of complete tank tests of NACA models 22-A and 35, two flying-boat hulls of the deep-pointed-step type with low dead rise, are presented. Model 22-A is a form derived by modification of model 22, the test results of which are given in abstract 123. Model 35 is a form of the same type but has a higher length-beam ratio than either model 22 or 22-A.

Take-off examples are worked out with data from these tests and a previous test of a conventional model applied to an arbitrary set of design specifications for a 15,000-pound flying boat. The comparison of these examples shows both pointed-step models to be superior to the conventional form and model 35 to be the better of the two.

Model 35 is applied to a hypothetical 100,000-pound flying boat of the twin-hull type and performance calculations are made for both take-off and range. The results indicate that the high performance of this type of hull will enable the designer to use higher wing and power loadings than are found in current practice, with a resulting increase in range and pay load.

129. Bell, Joe W.: The Effect of Depth of Step on the Water Performance of a Flying-Boat Hull Model - N.A.C.A. Model 11-C. NACA TN No. 535, 1935.

NACA model 11-C was tested in Langley tank no. 1 with four different depths of step to obtain information as to the effect of the depth of step on the resistance characteristics. The depths of step were selected to cover the practicable range of depths, and in each case the included angle between the forebody and afterbody keels was $6\frac{1}{2}^{\circ}$.

The smaller depths of step were found to give lower resistance at speeds below and at the hump speed; the greater depths of step were found to give lower resistance at high speeds. For low resistance throughout the speed range of the model investigated, the most desirable depth of step was from 2.5 to 4.0 percent of the beam. The change in the best trim caused by variation of the depth of step was small. Increased depths of step caused increases in the maximum positive trimming moments at all trims investigated.

130. Bell, Joe W., Garrison, Charlie C., and Zeck, Howard: Effect of Length-Beam Ratio on Resistance and Spray of Three Models of Flying-Boat Hulls. NACA ARR No. 3J23, 1943.

An investigation of the effect of changes in the length-beam ratio of flying-boat hulls on resistance and spray was conducted in Langley tank no. 1. A family of three models of hulls of different length-beam ratios was used and, in order to maintain comparable hull sizes, the plan-form areas of the hulls were made approximately equal by keeping equal products of length and beam.

The tests were made by the general method for the fixed-trim condition as well as by the specific method for the free-to-trim condition. Photographs of the spray were taken during the free-to-trim tests. Resistance and trimming-moment data obtained from the tests were compared over a wide range of loads at best-trim and free-to-trim conditions. Further comparisons were made by means of take-off calculations for hypothetical flying boats that incorporated the lines of the models.

The spray photographs indicated that at very low speeds the height of the bow spray was reduced by increasing the length-beam ratio, but at high speeds the height of the spray was increased slightly by increasing length-beam ratio. It was concluded from the results of the tests that by increasing the length-beam ratio the useful load coefficient may be increased and that, within the range of the tests, high length-beam ratios will give lower hump resistance and better take-off performance than low length-beam ratios.

131. Dawson, John R.: The Effect of Spray Strips on a Model of the P3M-1 Flying-Boat Hull. NACA TN No. 462, 1933.

Specific resistance tests were made in Langley tank no. 1 of a $\frac{1}{6}$-size model of the hull and side floats of the Navy P3M-1 flying boat for the purpose of finding a method of reducing the amount of spray thrown into the propellers of this craft when taking off and landing.

The model was tested without spray strips and with five different spray-strip arrangements. The best arrangement was an improvement over the bare hull with no spray strips, but the improvement was not sufficient to be satisfactory with the propellers in the designed position.

132. Allison, John M.: The Effect of the Angle of Afterbody Keel on the Water Performance of a Flying-Boat Hull Model. NACA TN No. 541, 1935.

General resistance tests were made in Langley tank no. 1 of NACA model 11-C with the afterbody keel set at five different angles ranging from $2\frac{1}{2}^\circ$ to $9^\circ$ $\left(3\frac{1}{2}^\circ \text{ to } 10^\circ \text{ with forebody keel}\right)$; other features of the hull remained unchanged. The results of the tests are expressed in curves of test data and of nondimensional coefficients.

At the depth of step used in the tests, 3.3 percent beam; the smaller angles of afterbody keel gave greater load-resistance ratios at the hump speed and smaller ratios at high speed than the larger angles of afterbody keel. Comparisons are made of the load-resistance ratios at several other points in the speed range.

The effect of variation of the angle of afterbody keel upon the take-off performance of a hypothetical flying boat of 15,000 pounds gross weight having a hull of model 11-C lines is calculated, and the calculations show that the craft with the largest of the angles of afterbody keel tested, 9°, takes off in the least time and distance.

133. Bell, Joe W., and Willis, John M., Jr.: The Effects of Angle of Dead Rise and Angle of Afterbody Keel on the Resistance of a Model of a Flying-Boat Hull. NACA ARR, Feb. 1943.

A series of models of flying-boat hulls was tested in Langley tank no. 1 to determine the effects of the angle of dead rise and the angle of afterbody keel on resistance and spray characteristics. Three angles of dead rise, $14\frac{3}{4}^{\circ}$, $19^{\circ}$, and $23\frac{1}{4}^{\circ}$, and three angles of afterbody keel, $4^{\circ}$, $6\frac{1}{4}^{\circ}$, and $8\frac{1}{2}^{\circ}$, were investigated. The tests included nine configurations incorporating all possible combinations of these values. The results of the tests are expressed in non-dimensional coefficients.

The effect of angle of dead rise on resistance and best trim was negligible up to and including the hump. At higher speeds, the resistance was reduced by the lower dead rise and increased by the higher dead rise. These differences, however, were relatively small.

At small angles of afterbody keel, the resistance was low at low speeds and high at planing speeds. The positive trimming moments were reduced by reducing the angle of afterbody keel. High angles of afterbody keel gave a higher best trim at the hump and at planing speeds.

The effects of angle of afterbody keel were consistent at all angles of dead rise and the effects of dead rise were consistent at all angles of afterbody keel.

134. Baker, G. S., and Keary, E. M., in Conjunction with Capt. Gundry and Lieut. Hackforth: Experiments with Full-Sized Machines. First Series. R. & M. No. 473, British A.C.A., 1919.

Tests were made of a full-size flying boat having a gross weight of 4000 pounds and the results of the tests were compared with those of a model of the hull made at the William Froude National Tank.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

Porpoising tests were made by noting the trim and behavior of the flying boat during accelerated runs with various fixed elevator deflections. Porpoising tests were also made at overloads of 4650 and 4850 pounds. The flying boat was able to take off at all loads tested. The resistance was determined by towing the flying boat from a destroyer at various speeds. The flying boat was taxied at several engine speeds, and the speed and trim were measured.

The results of the tests show that the resistance and trim predicted from model tests were reasonably close to those of the full-size flying boat up to about one-half the flying speed, that the change-over from ploughing to planing conditions took place at corresponding speeds, and that the general behavior of the full-size flying boat was the same as that predicted from the model.

135. Baker, G. S., and Keary, E. M.: Experiments with Model Flying Boat Hulls and Seaplane Floats: Nineteenth Series. Possibility of Loading a Flying Boat, the Beam and Angle of Forebody Being Varied. R. & M. No. 655, British A.C.A., 1920.

Specific free-to-trim tests were made at the William Froude National Tank of several models having different forebody beams to determine the effects of gross load and beam on resistance and seaworthiness characteristics.

For a given beam increasing the gross load increased the hump speed slightly. With increasing gross load the load-resistance ratio increased at speeds less than and decreased at speeds greater than hump speed, and the trim decreased at speeds less than and increased at speeds greater than hump speed.

For a given gross load increasing the beam decreased the hump speed, increased the resistance at and less than hump speed, and increased the trim. At high planing speeds increasing the beam increased the resistance.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

Varying the width of the rear step had little effect on the resistance characteristics. Increasing the angle between the forebody and afterbody keels increased the resistance and the height of the bow spray.

The division of the total load and resistance between the forebody and afterbody of two models was determined at hump speed and at a planing speed. The afterbody contributed only a small part of the total resistance, and hence the increase of resistance with increase of angle between forebody and afterbody keels was caused by the increase in forebody resistance. The load-resistance ratio of the afterbody was greater than that of the forebody.

A description of the towing gear and method of testing is given in an appendix. Conversion of model data to full-size results is discussed.

136. Truscott, Starr: Experiments with Models of Edo Float Model P and Seversky Float (Seversky 3213). NACA MR, Rep. No. S-1, Nov. 24, 1931.

Specific fixed-trim and free-to-trim resistance tests were made of two models of floats supplied by the Edo Aircraft Corporation. NACA model 7 is one of the standard forms made by Edo Aircraft Corporation, the performance of which is well known. The model of the Seversky float, NACA model 8, is a special design intended for use on a twin-float amphibian seaplane of high speed. A retractable wheel is fitted in a central well in the Seversky float. This location is intended to avoid the water resistance of the immersed wheel while taking off and also the air resistance of the wheel while in flight. The well is open at top and bottom. Tests were also made on model 7 with a central well. Test data and results are presented in the form of tables and curves.

137. Baker, G. S., and Keary, E. M.: Experiments with Models of Flying Boat Hull. Sixteenth Series. R. & M. No. 472, British A.C.A., 1919.

Specific free-to-trim resistance tests of models of two flying-boat hulls having a gross weight of 32,000 pounds were made at the

William Froude National Tank. The two models were the N.4 and one designed by the Gosport Aviation Company, Ltd., with modifications to improve the resistance characteristics. As it was desired to determine whether the spray would hit the propellers of the N.4, the model was fitted with skeleton wings and wire rings simulating the propeller disks and observations of the spray were made at low speeds. A discussion is given of the design of the wing-tip floats of the Gosport flying boat for the conditions of planing at high speed in waves and riding at anchor in a cross wind.

138. Baker, G. S., and Millar, G. H.: Experiments with Models of Hydro-Aeroplane Floats. Second and Third Series. R. & M. No. 98, British A.C.A., 1915.

Second Series

A description is given of the towing apparatus of the William Froude National Tank as modified to allow the determination of trimming moment.

Specific resistance tests at 6° trim were made of a series of floats in which the angle of afterbody keel was varied from -5° to 12° with respect to the forebody keel. In order to keep the total buoyancy approximately constant, the sides of the afterbody were swelled out as the afterbody keel was raised. Step ventilation by means of air holes from the step to the deck of the float decreased the hump in the power curve. Ventilation should be concentrated near the keel. The effects on resistance of varying the trims of a single float and the spacing between twin floats were investigated.

Third Series

Specific resistance tests at 6° trim were made of single floats that have the same length and double the breadth as those of the second series. One float had a flat bottom, and the other three floats had tunnel forebodies. The least power was required by the float with a tunnel forebody, and the hump power was about the same as that of a pair of one of the floats of the second series.

Wind-tunnel tests were made of one of the floats of the second series.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

139. Baker, G. S., and Millar, G. H.: Experiments with Models of Hydro-Aeroplane Floats. Fourth Series. R. & M. No. 99, British A.C.A., 1915.

Specific fixed-trim resistance tests of several models of two-step floats were made at the William Froude National Tank. A rounded bottom was found to be more efficient than a flat bottom (not curved transversely) and has the advantage of being stronger and more favorable for easy landing. Diagrams showing the trimming moment about the center of gravity of the seaplane for various positions of the floats relative to the center of gravity and the method of constructing the diagrams are given.

140. Baker, G. S.: Experiments with Models of Seaplane Floats. Sixth Series. R. & M. No. 165, British A.C.A., 1919.

Specific resistance tests were made at the William Froude National Tank of several models of floats for three-float seaplanes. The tail float was the same for all models. The models were run free to trim at speeds up to hump speed when the tail float came off the water and the models tended to oscillate in pitch. At speeds greater than hump speed, the models were run at a fixed trim of 6° with the tail float out of the water.

A toboggan or flat-bottomed stepless float requires slightly less power at the hump and more power at high speed than a boat-shaped float. The boat-shaped form of float is the stronger. The toboggan type has been abandoned by hydroplane designers.

141. Baker, G. S.: Experiments with Models of Seaplane Floats. Seventh Series. R.& M. No. 166, British A.C.A., 1919.

Specific resistance tests were made at the William Froude National Tank of several models of floats for single-float seaplanes. The models were run free to trim at low speed. At high speed the models were balanced until they ran with both steps in the water. One model with a single step was tested at high speed at two fixed trims. The trims were such that the tail was in the water in one case and out of the water in the other case. The resistance with the tail out of the water was less than the resistance with the tail in the water.

Some tests were made at one high speed and various trims. All the models with two steps showed a pronounced increase in resistance at trims at which the two steps were in contact with the water and another increase in resistance at trims at which the tail was in the water.

142. Baker, G. S., and Bottomley, G. H.: Experiments with Models of Seaplane Floats. Eighth Series. R. & M. No. 137, British A.C.A., 1919.

Specific resistance tests were made at the William Froude National Tank of several models of seaplane floats having a large beam over the chines compared with the width of the main body of the float and a long afterbody. The effect of trim on resistance at a high speed was determined for two models. When the afterbody was in the water, the resistance increased with increasing trim.

A model with a narrow beam had less resistance at moderate speeds and a higher hump speed than one with a wide beam. The resistance of a straight V-bottom was less than that of a curved V-bottom with chine flare. The model with the straight V-bottom threw large blisters of spray, which were not thrown by the model with the curved V-bottom with chine flare. An afterbody with a flat bottom had less resistance than one with a convex curved bottom; more water clung to the sides of the curved bottom. Strips on the forebody bottom at the chines reduced the amount of spray and had little effect on resistance.

143. Baker, G. S., and Keary, E. M.: Experiments with Models of Seaplane Floats. Tenth Series. R. & M. No. 189, British A.C.A., 1919.

Specific tank tests of models of several types of main floats for three-float seaplanes were made at the William Froude National Tank. Adding horizontal strips to the sides at the chines reduced the resistance at hump speed. One model was tested at two values of gross weight. The maximum effective horsepower increased approximately with the gross weight.

144. Baker, G. S., and Keary, E. M.: Experiments with Models of Seaplane Floats. Eleventh Series. Parts I and II. R. & M. No. 300, British A.C.A., 1919.

Part I

Specific free-to-trim resistance tests were made at the William Froude National Tank of three models having the same length but different beams (relative beams of 1, 3/4, and 1/2). The trimming moment due to propeller thrust was simulated.

For all the models, the hump speed increased and the load-resistance ratio at the hump decreased with increasing gross load. For a given gross load the hump speed and the hump resistance increased and the ratio of hump speed to get-away speed decreased with increasing get-away speed. The model with the narrowest beam had the lowest resistance at low speeds and the highest hump speed and hump resistance. This model also had a tendency to oscillate in heel in the region of hump speed. Moving the center of gravity forward had little effect on the resistance but with the heavier loadings caused the floats to be extremely dirty at low speeds.

Part II

Tests were made to determine a modification of the float with the largest beam that would eliminate or reduce the heavy wetting of the tail at low speeds. The most satisfactory modification, from the point of view of wetting and resistance, was one having a transverse second step and a low dead rise toward the tail.

145. Baker, G. S., and Keary, E. M.: Experiments with Models of Seaplane Floats. Twelfth Series. R. & M. No. 412, British A.C.A., 1919.

A new method of towing is described in which the model pivots about the center of gravity but is towed from a point corresponding to the line of thrust.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

Specific free-to-trim resistance tests were made at the William Froude National Tank to develop a float having a short forebody and no tail aft of the second step. Tests were also made of three floats with various plan forms of the afterbody. The effect of varying the fore and aft position of the center of gravity was investigated; a forward position resulted in porpoising at low speeds, and a more forward position resulted in diving at low speed and increased bow spray. One form of float was tested at various loads, and the trimming moment required to produce diving at low speeds was measured; this test showed that overloading would cause the float to dive. Some landing tests were made but were not considered to be strictly applicable to the full-size seaplane.

146. Baker, G. S., and Keary, E. M.: Experiments with Models of Seaplane Floats. Seventeenth Series Report. R. & M. No. 483, British A.C.A., 1919.

Specific free-to-trim resistance tests were made at the William Froude National Tank of models of the hulls of various flying boats. Modifications were made to one of the models to improve the resistance characteristics. In nearly every case the application of a bow-down trimming moment brought on violent pitching oscillations, and in some cases a large stalling moment also brought on instability. The limits of moment for stable running are given for two of the models. Changing the step on one model from a straight transverse step to various degrees of V-step slightly increased the resistance at high speeds and increased the height of the bow spray.

147. Truscott, Starr: Further Tests of Model of Glenn L. Martin Company Flying-Boat Hull - Model No. 130. NACA MR, April 11, 1933.

Specific fixed-trim and free-to-trim resistance tests were made of a $\frac{1}{8}$-size model of the Glenn L. Martin flying-boat hull to determine the effect on resistance of fitting corrugations on the bottom of

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

the hull to simulate corrugated structural bottom plate. In one case the forebody was fitted with corrugations from well forward to the main step; in the other case the corrugations extended from well forward to the main step and from the main step to the second step. The data are tabulated and plotted and a complete set of spray pictures is included.

148. Carter, Arthur W.: General Free to Trim Tests in NACA Tank No. 2 of Three 1/8-Full-Size Models of Flying-Boat Hulls at Low Speeds - NACA Models 116E-3k, 120R, and 143. NACA MR, Bur. Aero., Jan. 19, 1943.

Tests of representative models of three flying-boat hulls were made to determine the resistance at low speeds both forward and astern. The models were tested free to trim by the general method and readings were made of the trim, draft, resistance, and speed. These data were requested by the Bureau of Aeronautics for use in solving problems involving the hull resistance of a towed or a drifting flying boat.

149. Locke, F. W. S., Jr.: General Resistance Tests on Flying-Boat Hull Models. NACA ARR No. 4B19, 1944.

This report reexamines known procedures for handling "general" resistance testing on flying-boat hull models, with particular reference to saving testing time and to improving the usefulness of results to the designer.

It is concluded that the following relationships for collapsing the data from general resistance tests will provide satisfactory accuracy for all loads within practicable limits and that their use permits a considerably large reduction in the number of tests required, besides presenting the results in a simple form for ready use:

1. For the displacement range of speeds, using free-to-trim tests with the longitudinal center of gravity located to provide proper trim in the planing range

$$\frac{C_R}{{C_\Delta}^{2/3}\ {C_V}^2} = \phi\left(\frac{{C_V}^2}{{C_\Delta}^{1/3}}\right)$$

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

2. For the planing range of speeds, using fixed-trim tests and making trim a parameter

$$\sqrt{C_R}/C_V = \phi\left(\sqrt{C_\Delta}/C_V\right)$$

where $C_R$, $C_\Delta$, and $C_V$ are coefficients of resistance, load, and speed, respectively, based on Froude's law.

150. Dawson, John R., and Truscott, Starr: A General Tank Test of a Model of the Hull of the British Singapore IIC Flying Boat. NACA TN No. 580, 1936.

A general resistance test was made in Langley tank no. 1 of a $\frac{1}{12}$-size model of the hull of the British Singapore IIC flying boat lent by the Director of Research, British Air Ministry. The results are given in charts and are compared with the results of tests of a model of an American flying-boat hull, the Sikorsky S-40. The Singapore hull has a greater hump resistance but a much lower high-speed resistance than the S-40. The results of the tests are also compared with the results from tests of the same model that were made in the British R.A.E. tank, and the agreement is found to be good when sufficient data were available to be conclusive.

151. Dawson, John R.: A General Tank Test of a Model of the Hull of the P3M-1 Flying Boat Including a Special Working Chart for the Determination of Hull Performance. NACA TN No. 681, 1938.

The results of a general resistance test of a $\frac{1}{6}$-size model of the hull of the P3M-1 flying boat (NACA model 18) are given in non-dimensional form. In addition to the usual curves, the results are presented in a new form (working charts) that makes it possible to apply them more conveniently than in the forms previously used.

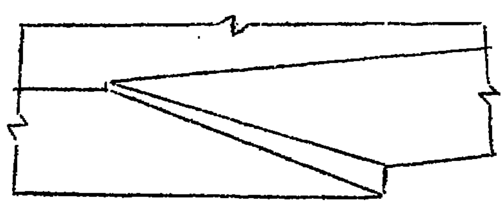
The resistance was compared with that of NACA models 11-C and 26 (Sikorsky S-40) and was found to be generally less than the resistance of either.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

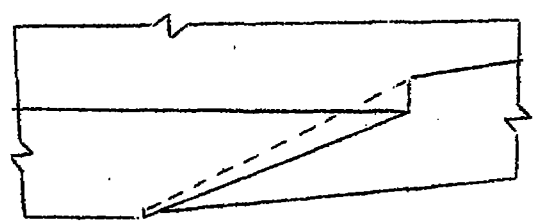
152. Dawson, John R.: A General Tank Test of N.A.C.A. Model 11-C Flying-Boat Hull, Including the Effect of Changing the Plan Form of the Step. NACA TN No. 538, 1935.

Tests were made of NACA model 11-C (model 11-A with improved bow lines) to determine its resistance characteristics with various plan forms of the step. The variations included a transverse step, three angles of V-step (15°, 30°, and 45°), and three angles of swallow-tail step (15°, 30°, and 45°). The steps were so arranged that the average depth of step was equal to that of the transverse step.

The water resistance of model 11-C with the transverse step was greater than that of 11-A for all loads at the hump, but there was little difference in the high-speed resistance of the two models. With the exception of the 45° swallow-tail step, which was impracticable because of the small depth of step at the keel, the swallow-tail step and the V-step did not greatly affect the resistance characteristics measured in the tank tests.



V-step



Swallow-tail step

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

153. Davidson, Kenneth S. M., and Locke, F. W. S., Jr.: General Tank Tests on the Hydrodynamic Characteristics of Four Flying-Boat Hull Models of Differing Length-Beam Ratio. NACA ARR No. 4F15, 1944.

The main purpose of this report is to present the results of "general" tests on the hydrodynamic characteristics of four related flying-boat hull models of differing length-beam ratio $L/B$ (5.07, 6.19, 7.32, 8.45). The length-beam ratio was altered by expanding the forebody and afterbody lengths in the same ratio and without changing step height or afterbody keel angle. The load program was evolved from a relationship in which gross load coefficient $C_{\Delta_0}$ was proportional to $(L/B)^3$. The results were compared on the basis of constant beam and constant length-beam product.

In general it has been found that increasing the length-beam ratio

(1) Helps the hump resistance and trim but shifts the hump to higher speed

(2) Helps the high-speed resistance

(3) Injures the stable range of trim angles

(4) Lowers the height of main spray blister

(5) Reduces the bow spray at taxying speeds in rough water

(6) Injures the yawing stability slightly, though not materially altering the speed ranges for the various types of yawing stability

It is believed that the beam loading cannot be increased as rapidly as in proportion to the cube of the length-beam ratio without important sacrifices in respect to one or more of the principal hydrodynamic characteristics: resistance, porpoising, or main spray. A rate proportional to the square of the length-beam ratio appears to be more nearly the maximum possible.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

154. Parkinson, John B., Olson, Roland E., and House, Rufus O.: Hydrodynamic and Aerodynamic Tests of a Family of Models of Seaplane Floats with Varying Angles of Dead Rise.- N.A.C.A. Models 57-A, 57-B, and 57-C. NACA TN No. 716, 1939.

Three models of V-bottom floats for twin-float seaplanes (NACA models 57-A, 57-B, and 57-C) having angles of dead rise of 20°, 25°, and 30°, respectively, were tested in Langley tank no. 1 and in the Langley 7- by 10-foot tunnel. Within the range investigated, the effect of angle of dead rise on water resistance was found to be negligible at speeds up to and including the hump speed, and water resistance was found to increase with angle of dead rise at planing speeds. The height of the spray at the hump speed decreased with increase in angle of dead rise and the aerodynamic drag increased with angle of dead rise.

Lengthening the forebody of model 57-B decreased the water resistance and the spray at speeds below the hump speed. Spray strips provided an effective means for the control of spray with the straight V-sections used in the series but considerably increased the aerodynamic drag.

Charts for the determination of the water resistance and the static properties of the model with 25° dead rise and for the aerodynamic drag of all the models are included for use in design.

155. Dawson, John R., and Hartman, Edwin P.: Hydrodynamic and Aerodynamic Tests of Four Models of Outboard Floats (N.A.C.A. Models 51-A, 51-B, 51-C, and 51-D). NACA TN No. 678, 1938.

Four models of outboard floats (NACA models 51-A, 51-B, 51-C, and 51-D) were tested in Langley tank no. 1 to determine their hydrodynamic characteristics and in the Langley propeller-research tunnel to determine their aerodynamic drag. The results are compared and presented in the form of charts.

The tank data indicated that:

(1) For minimum spray from the float or for minimum angle of heel of the seaplane, the planing surface of the float should have a wide stern and a low dead rise.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

(2) The inclusion of a step, or other equivalent discontinuity, with a properly formed afterbody allows the use of a wide planing surface without sacrificing performance in the drifting condition.

(3) The greatest structural loads will be obtained from the float with the most effective planing surface.

The wind-tunnel data indicated that:

(1) The float that may be set with its chines most nearly in line with the direction of flight in cruising is likely to be the best float from considerations of air drag.

(2) All chines or other sharp intersections in the cross section should be avoided except where they are definitely necessary for hydrodynamic reasons.

(3) In order to obtain low air drag, it is desirable that the angle of float setting be as small as practicable.

156. Parkinson, J. B., and House, R. O.: Hydrodynamic and Aerodynamic Tests of Models of Floats for Single-Float Seaplanes - N.A.C.A. Models 41-D, 41-E, 61-A, 73, and 73-A. NACA TN No. 656, 1938.

Tests were made in Langley tank no. 1 and in the Langley 7- by 10-foot tunnel of two models of transverse-step floats and three models of pointed-step floats considered to be suitable for use with single-float seaplanes. The models were designed at Langley tank no. 1 as part of a program established to reduce the water resistance and spray of single-float seaplanes without reducing the angle of dead rise believed to be necessary for the satisfactory absorption of the shock loads.

The form of NACA model 41-D is similar to that of the Navy Mark V float (NACA model 41-A) but has more gradual fore- and aft-curvature of the buttock lines near the steps and a lower angle of afterbody keel.

NACA model 41-E is a modification of model 41-D, the rear step having been eliminated. NACA model 61-A has a pointed step with a horizontal afterbody similar to NACA model 35-B. NACA model 73 is a refinement of the pointed-step form, in which a fairing has been fitted above and behind the step. NACA model 73-A is a modification of model 73, the chine being wider and higher near the bow for greater seaworthiness in rough water.

All the models were tested in the Langley tank free to trim at one gross load. The results indicated that all the models have less resistance and spray than the model of the Mark V float and that the pointed-step floats are somewhat superior to the transverse-step floats in these respects. Models 41-D, 61-A, and 73 were tested by the general method over a wide range of loads and speeds; the results are presented in the form of curves and charts for use in design calculations.

The aerodynamic drag of the models was determined in the Langley 7- by 10-foot tunnel at angles of pitch from -10° to 16°. Models 61-A and 73 have the lowest minimum drag coefficient and model 73-A has the highest. The difference between models 41-D and 41-E is negligible. The fairing of the pointed step had only a small effect on the water resistance and aerodynamic drag.

157. Truscott, Starr, Parkinson, J. B., Ebert, John W., Jr., and Valentine, E. Floyd: Hydrodynamic and Aerodynamic Tests of Models of Flying-Boat Hulls Designed for Low Aerodynamic Drag - N.A.C.A. Models 74, 74-A, and 75. NACA TN No. 668, 1938.

NACA models 74, 74-A, and 75 were tested in Langley tank no. 1 to determine their hydrodynamic properties and in the Langley propeller-research tunnel to determine their aerodynamic properties. The forms of these models were derived from the form of a solid of revolution having a low air drag, and the departures from the form of this low-drag body were the minimum considered to give satisfactory take-off performance. Model 74 has a rounded bottom with flared chines, a transverse step with a small fairing aft of it, and a pointed afterbody. Model 74-A has the same form except for the removal of the fairing aft of the step. Model 75 has a pointed step and a horizontal afterbody derived from the form of the NACA model 35 series.

General free-to-trim and fixed-trim resistance tests were made in the tank and the data are presented in the form of resistance and trimming-moment coefficient against trim. The wind-tunnel results are given as drag coefficient against trim. The take-off performances of models 74-A and 75 are compared by take-off calculations for a hypothetical seaplane having 250,000 pounds gross weight.

When compared on the basis of equal volumes, each of the models has a lower aerodynamic drag than any model of a conventional hull tested in the propeller-research tunnel. Model 74-A has lower drag than model 75 but model 75 has lower resistance at high speeds on the water and better take-off performance for the hypothetical seaplane investigated. The aerodynamic refinement leads to high water resistance at certain combinations of trim and load, but satisfactory take-off performance can be attained by proper control of the trim.

158. Ward, Kenneth E.: Hydrodynamic Tests in the N.A.C.A. Tank of a Model of the Hull of the Short Calcutta Flying Boat. NACA TN No. 590, 1937.

The resistance characteristics of a model of the hull of the Short Calcutta (NACA model 47) are presented in nondimensional form. This model represents one of a series of hulls of successful foreign and domestic flying boats, the characteristics of which are being obtained under similar test conditions in Langley tank no. 1.

The take-off distance and time for a flying boat having the hull of the Calcutta are compared at two values of the gross load with the corresponding distances and times for the same flying boat having hulls of two representative American types, the Sikorsky S-40 and the NACA 11-A. This comparison indicates that, for hulls of the widely different forms compared, the differences in take-off time and distance are negligible.

159. Olson, Roland E., and Lina, Lindsay J.: Hydrodynamic Tests of a 1/10-Size Model of the Hull of the Latécoère 521 Flying Boat - NACA Model 83. NACA TN No. 836, 1941.

A $\frac{1}{10}$-size model of the hull of the French flying boat Latécoère 521 was tested without stub-wing stabilizers in Langley tank no. 1.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

Tests were made with and without the tail extension to determine the effect of the tail extension on the hydrodynamic forces and moments.

Free-to-trim resistance tests were made at the design gross load (gross load coefficient of 0.428) and general resistance tests were made at load coefficients from 0.025 to 0.6. The spray characteristics of the model are good. The form of the bow would be particularly desirable for rough-water use. The interference of the afterbody and the tail extension is excessive and causes very high resistance at high speeds. A violent vertical instability is present at trims of 4° and 6° with light loads and high speeds.

160. Eula, Antonio: Hydrodynamic Tests of Models of Seaplane Floats. NACA TM No. 770, 1935.

Results of tank tests carried out free to trim on seventeen hulls and floats of various types are presented. The data on the weight on water, trim, and relative resistance for each model are plotted nondimensionally and are referred both to the total weight and to the weight on the water. Despite the fact that the experiments were not made systematically, a study of the models and of the test data permits some general deductions regarding the forms of floats and their resistance. One specific conclusion is that the best models have a maximum relative resistance not exceeding 20 percent of the total weight.

161. Bladen, D. H.: Method of Computing Corresponding Speeds, Loads and Resistances of Planing Bodies. Rep. No. 839, Edo Aircraft Corp., Dec. 23, 1941.

A method is developed by which a given take-off resistance curve may be used to extrapolate any desired resistance curve with different take-off conditions. The wave-making resistance is neglected and use is made of the planing relationship $\Delta/V^2$ where $\Delta$ is the load on the water and $V$ is the speed. The regular take-off equations are handled by making trigonometric substitutions. The method has been checked and a correction factor has been formulated which adequately corrects errors occurring at the lower speeds.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

162. Locke, F. W. S., Jr.: Preliminary Resistance Tests in Shallow Water of a 1/30-Scale Model of the Hull of the XPB2M-1 Flying Boat. Rep. No. 193, Stevens Inst. Tech., Sept. 1, 1942.

Free-to-trim resistance tests were made of a $\frac{1}{30}$-size model of the hull of the XPB2M-1 flying boat by the "specific" method in depths of water ranging from depth-beam ratios of 0.46 to 1.85 and over a speed range corresponding to values of speed coefficient $C_V$ from 0.8 to 3.0. A few tests of the same type were made at a depth-beam ratio of 0.37 in the vicinity of the hump.

It was found that the take-off time of a modern, heavily loaded flying boat will not be seriously affected by shallow water, provided the depth of water is not less than the hull beam. Lesser depths have an adverse effect, in general, though in the region of the true hump a depth of about one-half the beam results in some improvement in resistance.

The tests indicated that, if the idea of basing flying boats on very shallow water were to be considered seriously, attention should be directed to developing a hull which is able to get over the hump without water clinging to the afterbody sides and tail cone, thus eliminating the peak in the resistance curve before the true hump.

163. Dawson, John R., and Wadlin, Kenneth L.: Preliminary Tank Tests with Planing-Tail Seaplane Hulls. NACA ARR No. 3F15, 1943.

Preliminary tests were made with simplified models of two types of hull having a single main planing surface combined with afterplaning surfaces that were fitted to tail booms.

The type of hull with twin-tail booms can be arranged in such a manner that the air drag probably could be made lower than that of the equivalent conventional hull, although water resistance would be increased. The structural problems inherent in the arrangement, however, may be prohibitive.

The type of hull with a single tail boom is found to give lower resistance than conventional hulls and to have desirable trim characteristics. Indications are that the stability characteristics would be satisfactory.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

Hulls with planing tails have high trims at rest, have less room for useful load aft of the center of gravity than conventional hulls, and introduce restrictions on the types of tail surfaces that may be used.

164. Fuller, Dell: Report of Resistance Tests of 10.5 L/B Ratio Hulls and Comparison with DVL Family. Rep. No. ZH-019, Consolidated Vultee Aircraft Corp., May 22, 1944.

This report summarizes the results of tests of three flying-boat hulls with length-beam ratio of 10.5 tested at Langley tank no. 1 and reported in abstract 167. The take-off time of a hull with a length-beam ratio of 10.5 was compared with the take-off time of other hulls of the DVL family and it was found that by holding the beam constant and varying the length the lowest take-off time would occur at a length-beam ratio of 9.

165. Land, Norman S., Bidwell, Jerold M., and Goldenbaum, David M.: The Resistance of Three Series of Flying-Boat Hulls as Affected by Length-Beam Ratio. NACA ARR No. L5G23, 1945.

Data obtained from several independent length-beam-ratio investigations were correlated in order to determine the general effect of length-beam ratio on the resistance characteristics of three series of flying-boat hulls. The study involved length-beam ratios ranging from 5.07 to 10.5 for a large range of loading conditions. Analyses were made at the best-trim hump, the free-to-trim hump, and a high-speed condition near get-away.

Comparisons were made by use of coefficients based on beam, length-beam product, and length$^2$-beam product; the bases for these coefficients are those most commonly given in the various sources of information. An optimum length-beam ratio was found beyond which no further reduction in hydrodynamic resistance occurred. This optimum varied with the hull lines of the series.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

166. Bell, Joe W.: Resistance Tests of a 1/40-Size Model of the Hull of the HK-1 Cargo Airplane, NACA Model 155. NACA MR, Dept. Commerce, Jan. 4, 1943.

General fixed-trim and free-to-trim resistance tests were made on a $\frac{1}{40}$-size model of the HK-1 cargo airplane. Because of the small size of the model and the difficulties of testing it by use of the relatively large and heavy equipment, the results of the tank tests should be considered preliminary. Two take-off calculations were made with the hull assumed to be in the free-to-trim condition up to 60 and 70 feet per second, respectively, and at precision trim (trim for lowest air-plus-water resistance) to get-away.

The chines of the afterbody of the original model did not provide a break sharp enough to prevent the water from flowing up the sides and along the tail extension. The addition of chine flare to the afterbody improved the flow and caused marked improvements in the trim and resistance characteristics. The spray from the bow and the sides of the forebody appeared to be satisfactory both before and after the modification of the afterbody.

167. Bidwell, Jerold M., and Goldenbaum, David M.: Resistance Tests of Models of Three Flying-Boat Hulls with a Length-Beam Ratio of 10.5. NACA ARR No. L5G19, 1945.

Models of three flying-boat hulls, each with a length-beam ratio of 10.5, were tested at Langley tank no. 1. The lines of these models were derived from the DVL standard series. The three models permitted tests with two depths of step and two angles of dead rise. Resistance, trimming-moment, and wetted-length data were obtained from general fixed-trim and free-to-trim tests at load coefficients ranging up to 4.0.

The results showed that these three models had low hydrodynamic resistance at high load coefficients. At the free-to-trim hump, load-resistance ratios of 4.5 and 3.9 were attained at load coefficients of 1.5 and 3.5, respectively. Increasing the angle of dead rise, excluding chine flare, from 20° to 24.5° tended to increase the resistance and trimming moments at planing speeds. Changing the depth of step from 5 to 10 percent beam had little effect on the resistance. With conventional nacelle locations, excessive spray would enter the propellers at load coefficients over 3.0.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

168. Goldenbaum, David M.: Resistance Tests of Two Models of Hulls for a Large Flying Boat (NACA Models 77K-1 and 77K-A). NACA MR, Bur. Aero., May 23, 1944.

General and specific resistance tests of two models of flying-boat hulls, alike in all respects except beam, were made to determine the effect upon resistance and spray of refairing the lines of a hull, increasing the beam, increasing the length, removing the tail extension, and applying a thrust moment and step ventilation.

The resistance of the wax-altered form was found to be less than that of the reproduced model. Increasing the beam 8 percent had no significant effect on the resistance. Increasing the forebody length 21 percent markedly improved the low-speed resistance and rough-water spray characteristics. The removal of the tail extension increased the hump trim and thereby increased the hump resistance. Thrust moment reduced the maximum trim at the hump about $\frac{1}{2}^{\circ}$ and the hump resistance about 5 percent. Step ventilation eliminated the pre-hump discontinuity in the resistance-speed curve and appreciably reduced the magnitude of the resistance in that region.

169. Coombes, L. P.: Scale Effect in Tank Tests of Seaplane Models. Proc. Fifth Int. Cong. Appl. Mech. (Cambridge, Mass., 1938), John Wiley & Sons, Inc., 1939, pp. 513-519.

Evidence of scale effect observed during tests of models in the Seaplane Tank at the Royal Aircraft Establishment is described. Full-scale data were obtained from the Marine Aircraft Experimental Establishment at Felixstowe. The evidence was considered under three headings: resistance, stability, and spray formation.

In two cases where model and full-scale results were compared, the model tests showed lower resistance than the full-scale tests but in other cases this phenomenon did not exist. The small models were believed to have been operating under laminar-flow conditions, whereas the full-scale conditions were undoubtedly turbulent. With buoyant forces in the high-speed region considered constant, it was found that larger models, with subsequently higher Reynolds numbers, could be tested throughout the speed range by plotting the resistance as a function of $\Delta/V^2$ where $\Delta$ is the load on the water and $V$ is the velocity. This method allows a reliable extrapolation of data to speeds beyond the limiting speed of the carriage.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

The technique employed in stability tests at the R.A.E. is described briefly. Lack of agreement in results of stability between the model and full-scale seaplane is thought to be due to the difference in testing procedure and to such factors as slipstream and roughness of the planing bottom.

Scale effect on spray is due largely to surface tension - in the case of the model the spray comes off in sheets, whereas on the full-scale airplane the spray is well broken up.

170. Schmidt, Rudolph: The Scale Effect in Towing Tests with Airplane-Float Systems. NACA TM No. 326, 1937.

A three-component balance installed on actual airplanes for the purpose of testing full-size floats is described, and the results obtained from tests using this equipment are compared with those of two models of the same float but of different scale $\left(\frac{1}{2.5} \text{ and } \frac{1}{5}\right)$, which have been tested in the towing tanks at Hamburg and Berlin. The purpose of the comparison is to determine the effect of the Reynolds number on the results of tank model tests.

The theoretical part gives an explanation of the physical concept of scale effect. The scale effect is most conveniently analyzed by considering its effects on the tangential (friction) forces separately from those of the normal (pressure) forces. Based on the theoretically and experimentally determined laws for the coefficients of friction on plates in longitudinal flow, the methods in which both the Reynolds number for the three sizes of model and the coefficients of friction for plates at the same Reynolds number vary are investigated in a numerical example. The effect of the Reynolds number on the trimming moment takes the form of a change in the pressure distribution as a result of the separation phenomena, which may have a variety of causes. It was found that the method of influencing the pressure distribution and obtaining a better agreement between ship and model by means of a so-called "turbulence wire" used in tank tests of ship models is ineffectual on seaplane floats.

A numerical example shows that the order of magnitude of the scale effect on both friction and pressure forces is in magnitude and direction in satisfactory accord with theory and with the results from tests of planing surfaces if the rough assumptions are taken into account. By extrapolating for a 100,000-pound flying boat, a model scale must be chosen for which the Reynolds numbers correspond to those of the $\frac{1}{2.5}$-scale model. The scale effect then is approximately 50 percent of the frictional resistance of the model. Experiments also show that the scale effect may influence the calculations of the take-off time and distance in designs with different power loading.

171. Sottorf, W.: Scale Effect of Model in Seaplane-Float Investigations. NACA TM No. 704, 1933.

It is impossible to evaluate the full-scale resistance of planing water craft by the method of Froude because (1) the wetted surface varies with speed and with trim at the same speed, (2) the mean velocity of the water along the planing surfaces differs considerably from the towing speed, and (3) the determination of the frictional coefficients for the model is unreliable. A series of planing surfaces and floats has been investigated to determine the effects of scale on the various hydrodynamic considerations. Six flat planing surfaces having scale values $\frac{1}{\lambda}$ of 1, $\frac{1}{2}$, $\frac{1}{2.666}$, $\frac{1}{4}$, $\frac{1}{6}$, and $\frac{1}{8}$ and representing loads from 317 pounds to 0.62 pound were tested to determine the scale effects in the planing region. A float, from a twin-float seaplane, with models having scale values of $\frac{1}{3}$, $\frac{1}{6}$, $\frac{1}{9}$, and $\frac{1}{12}$ was used to determine the scale effects in the region of maximum resistance and to find out the interference effects of the afterbody.

The flat planing surfaces showed that the smaller the models the more unfavorable were the load-resistance ratios. It was found that the frictional coefficients of the surfaces differed from one another for the same Reynolds number. This difference was attributed to the fact that the load and the trim and hence the pressure increment affecting the boundary layer are dissimilar at the leading edge. In the investigated region there is a similarity of the wetted areas, similarity of the moments at the same trim, and consequently a consistent similarity of the pressure distribution.

The floats showed that with constant moment the maximum resistance (where $R_{fs} = \lambda^3 R_m$) was too high by 3.5 percent for $\lambda = 3$, 6 percent for $\lambda = 6$, 10.5 percent for $\lambda = 9$, and 21.5 percent for $\lambda = 12$,

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

and that with constant trim the maximum resistance was too high by 8.5 percent for $\lambda = 3$, 10.5 percent for $\lambda = 6$, 17 percent for $\lambda = 9$, and 25 percent for $\lambda = 12$. There was little difference in the resistance of the models until the change from displacement to planing occurred. The error in trim became more serious with the smaller models and amounted to as much as $4^{\circ}$ for the smallest model. It was found that the use of very small models would create an appreciable error in the take-off time, especially with small margins of excess thrust. Spray measurements showed that the relative height of the spray decreased as the size of the model was reduced, which can be explained by the effect of surface tension. It is believed that little error would be involved in the use of a $\frac{1}{8}$-full-scale model of a 21,000-pound flying boat; however, the use of about a $\frac{1}{6}$-scale model, if possible, is advised.

172. Herrmann, H.: Seaplane Floats and Hulls. Part I. NACA TM No. 426, 1927.

This report was prepared as a systematic digest of the important technical data on seaplane development accumulated in the years between 1912 and 1926. The characteristics of water resistance have been discussed and a method of graphically representing the data has been given. The laws of similarity and the theory of model tests have been introduced. The processes and the calculation of take-off have been reviewed and the triangle method of computing take-off time has for the first time been applied to seaplanes. Information on the effect of various design parameters on the performance of seaplanes and information on British impact investigations have been summarized.

173. Herrmann, H.: Seaplane Floats and Hulls. Part II. NACA TM No. 427, 1927.

The effect upon performance of changing some of the main design parameters has been discussed in relation to specific airplanes. The merits of twin-float seaplanes and flying boats have been discussed with reference to general considerations, seaworthiness, air resistance, water resistance, weight, and maneuverability. The merits of wood and metal hulls have been pointed out.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

The importance of static stability tests has been shown and an experimental method has been suggested. The merits of single-float seaplanes have been reviewed. Scale effect in model tests has been briefly discussed. The general resistance test and some performance characteristics have been described.

174. Baker, G. S., and Millar, G. H.: Some Experiments in Connection with the Design of Floats for Hydro-Aeroplanes. With an Appendix on Tests in the Wind Channel to Determine the Wind Forces on Hydro-Aeroplane Float No. 43B by L. Bairstow. R. & M. No. 70, British A.C.A., 1919.

Tests of a flat planing surface were made at the William Froude National Tank in which the lift and resistance were measured at various fixed values of draft, trim, and speed. The lift-resistance ratio was found to decrease with increasing trim (above 4°) and draft.

Specific fixed-trim tests of several models of floats for twin-float seaplanes with tail float were also made. Tests at one speed showed that the distance between floats on one type of twin-float seaplane had practically no effect on resistance or rise. Flat bottoms and straight keels were found to be more efficient than rounded bottoms and convex keels. Floats with a tail (afterbody) and a step give a smaller distance between the center of buoyancy at rest and the center of pressure at high speed than that of floats without a tail. It is of great importance that as the float rises nothing should prevent the access of air to the step. Step ventilation, produced by holes from the top of the float or by "mudguards" which prevent the water from clinging to the vertical sides near the step, successfully allowed air to flow to the step.

The lift and drag for various angles of pitch and the lateral and longitudinal forces for various angles of yaw were measured in wind-tunnel tests on one of the floats tested in the tank.

175. Parkinson, John B.: Specific Tank Test of a 1/8 Full-Size Model of the Hull of the XPBM-3 Flying Boat – NACA Model 120. NACA MR, Bur. Aero., Sept. 3, 1940.

Specific fixed-trim and free-to-trim resistance tests were made of a $\frac{1}{8}$-size model of the hull of the XPBM-3. Still and motion pictures were taken of the spray and some photographs are included.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

176. Dawson, John R.: A Specific Tank Test of a Model of the Hull of the Bureau of Aeronautics Design 182 Flying Boat - N.A.C.A. Model 96. NACA MR, Bur. Aero., April 14, 1939.

Specific fixed-trim and free-to-trim resistance tests were made of a $\frac{1}{12}$-size model of the hull of the Bureau of Aeronautics Design 182 flying boat. The results are presented with resistance, trim, trimming moment, load, and load-resistance ratio as functions of speed. Some typical photographs of the spray are included.

177. Dawson, John R., and Ebert, John W., Jr.: Specific Tank Tests of a Modification of a Model of the Hull of the XPB2M-1 Flying Boat - N.A.C.A. Model 94-F. NACA MR, Bur. Aero., Aug. 18, 1939.

Specific fixed-trim and free-to-trim resistance tests were made of one modification of a $\frac{1}{10}$-size model of the hull proposed for the XPB2M-1 flying boat. The model appeared to be similar to NACA model 94-A except for an increase in the angle of dead rise of the afterbody in the region just aft of the main step. These tests were made with three different gross loads; each gross load required a different position of the center of gravity and a different get-away speed. The results are presented with resistance, load, trim, trimming moment, and load-resistance ratio as functions of speed.

178. Parkinson, J. B., and Olson, R. E.: Specific Tank Tests of Two Models of Floats for the SB2U-3 and OS2U-1 Seaplanes - N.A.C.A. Models 106 and 107. NACA MR, Bur. Aero., Jan. 17, 1940.

Specific fixed-trim and free-to-trim resistance tests were made of two $\frac{1}{4}$-size models of Edo Aircraft Corporation designs 67-9000 and 68-9800, for use on the SB2U-3 and the OS2U-1 airplanes, respectively. The results are presented with resistance, trim, trimming moment, load, and load-resistance ratio as functions of speed. A number of spray photographs of each model are included.

179. Carter, Arthur M.: Specific Tests in NACA Tank No. 2 of Two Models of the Kaiser-Gar Wood Flying-Boat Hull - NACA Models 157A and 157B. NACA MR, The Aeronautical Board, March 31, 1943.

Specific fixed-trim and free-to-trim resistance tests were made of two models of the hull of a proposed Kaiser-Gar Wood flying boat. The models had sternpost angles of 3° and 6° with a tunnel-bottom forebody.

The model with the lower sternpost angle rode at a very low trim and tended to suck down in the medium speed range. At 6° fixed trim the forebody was clear and the model was riding on the afterbody; under these conditions, the model had a tendency to be directionally unstable.

The model with the large sternpost angle tended to porpoise at speeds just over the hump when the afterbody came clear. At 6° fixed trim the model was unstable in roll at high speeds. At low speeds and a trim of 3°, the model was directionally unstable.

The ratios of load on the water to resistance for the Kaiser-Gar Wood models were smaller at hump speeds and larger at high speeds than those for a conventional hull used for comparisons. In both cases the spray of the tunnel-bottom hulls was very low.

180. Anon.: Standard Series of Flying-Boat Hulls. Tests on Models for Resistance, Spray, and Porpoising for Bureau of Aeronautics, Navy Department. Note No. 23, Stevens Inst. Tech., Feb. 9, 1945.

Preliminary data from an extensive investigation to establish a framework of information on flying-boat hulls are presented for 17 models. The models have a length-beam ratio of 6.19 and include angles of dead rise from 0° to 40° and angles of afterbody keel from 3° to 11°. Charts are presented which show in summary form the trim, resistance, longitudinal stability, and spray characteristics of each model.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

181. Caldwell, R. W., and Fuller, Dell: Study of General Resistance Tests of High Length-Beam Ratio Hulls and Twin Hull Configurations. Rep. No. ZE-022, Consolidated Vultee Aircraft Corp., March 6, 1945.

An analysis of a general resistance test of five hulls having a length-beam ratio (L/B) of 10.5 is presented. These tests were made in Langley tank no. 1 of three hulls of DVL lines and proportions (abstract 167) that were an extension of the DVL length-beam ratio series and on two hulls of CVAC design. The CVAC hulls were identical and were tested as a twin-hull arrangement at various hull spacings. The main dimensions varied among the hulls were angle of dead rise and depth of step.

These tests indicated that:

(1) Substantial gains in resistance and take-off time can be made with high L/B hulls over conventional hulls of smaller L/B.

(2) An $\frac{L}{B} = 10.5$ hull using CVAC lines and a deeper step is superior in resistance to any of the DVL hulls tested.

(3) No significant interference effect on resistance occurs for the twin-hull arrangements tested.

(4) The spray patterns for the twin-hull arrangements were satisfactory and exhibited no abnormal characteristics for beam loadings up to a gross load coefficient of 3.5.

(5) In the case of large flying boats (150,000 lb or over), an increase in hydrodynamic performance would be attained by using twin hulls of high L/B and approximately the same total frontal area as a conventional hull of lower length-beam ratio.

182. Sabathe, Georges: Sur l'origine et la suppression de la discontinuité dans la résistance hydrodynamique des flotteurs d'hydravion. Comptes Rendus, t. 202, no. 22, June 2, 1936, pp. 1836-1838.

Model tests of seaplane floats often reveal a discontinuity in the resistance-speed curve immediately prior to the hump. This discontinuity has been attributed to a reduction of pressure behind the step, which may or may not be accompanied by cavitation. Ventilation of the low-pressure area by a tube or by a drain at either side of the step has successfully eliminated the discontinuity and has decreased the resistance in this region by as much as 25 percent.

183. Clark, K. W., and Hills, R.: Tank and Wind Tunnel Tests on the Short Sunderland to Compare Attitudes with Full Scale during Take-Off and Landing. Rep. No. B.A. 1622, British R.A.E., July 1940.

Tests were made to elucidate differences between model and full-scale attitudes during take-off.

Wind-tunnel tests of a $\frac{1}{12}$-scale model were made with and without ground effect represented up to large thrust coefficients. From the results, air lifts were estimated for tank tests under conditions for which attitudes of the full-scale seaplane had been recorded. From the measured air and pitching moments, attitude curves were evaluated to compare with full-scale results.

The wind-tunnel tests show an appreciable influence of ground effect on lift and a very large influence on pitching moments. When ground effect and the effect of the propeller slipstream are taken into account, the attitude curves of the model during take-off are in good agreement with the full-scale measured values.

184. Olson, Roland E., and Zeck, Howard: Tank Tests of a 1/16-Full-Size Model of the HK-1 Cargo Flying Boat. II - Resistance Tests of the Complete Models 158-1 and 158A and Brief Investigations of the Spray and Pressure Distribution on the Modified Tail Extension of Model 158A. NACA MR, Dept. Commerce, June 2, 1944.

The resistance of the $\frac{1}{16}$-size dynamic model of the Hughes-Kaiser cargo flying boat was determined by tests in Langley tank no. 1. The total resistance (hydrodynamic resistance of the hull and the aerodynamic drag of the complete model) at hump speeds was 18.2 pounds (75,000 lb, full scale) at a gross load of 97.0 pounds (400,000 lb, full scale). Increasing the diameter of the tail extension from $16\frac{1}{2}$ inches to 18 inches caused a slight increase in both the hump trim and the resistance. The spray characteristics with this tail extension, NACA model 158A, were slightly inferior to those of the original model, NACA model 158-1. The only negative pressures that were found on the tail extension occurred just aft of the sternpost. In general, positive pressures were found and the peak pressures occurred where the roach struck the tail extension.

185. Shoemaker, James M., and Parkinson, John B.: Tank Tests of a Family of Flying-Boat Hulls. NACA TN No. 491, 1934.

The results of resistance tests made in Langley tank no. 1 of a parent form and five variations of a model flying-boat hull are presented. The beams of two of the derived forms were made the same as the beam of the parent and the lengths changed by increasing and decreasing the spacing of stations. The lengths of two others of the derived forms were made the same as the length of the parent while the beams were changed by increasing and decreasing the spacing of the buttocks, all other widths being changed in proportion. The remaining derived form has the same length and beam as the parent, but the lines of the forebody were altered to give a planing bottom with no longitudinal curvature forward of the step.

The test data were analyzed to determine the minimum resistance and the angle at which it occurs for all speeds and loads. The results of this analysis are given in the form of nondimensional curves for each model.

It was found that increasing either the beam or the length resulted in an increase in the load-resistance ratio at the hump and a decrease at high speeds. The results showed rather conclusively that longitudinal curvature of the forebody should be avoided and that the length-beam ratio of the hull in the range tested (5.05 to 6.4) affects its planing performance principally because of the influence of this ratio on the secondary design factors.

186. Clark, K. W., and Coombes, L. P.: Tank Tests of a Family of Four Hulls of Varying Length to Beam Ratio. Rep. No. B.A. 1330, British R.A.E., Nov. 1936.

A family of four hulls of different beam, covering a range of over-all length-beam ratio from 5.5 to 10.0 and designed to have a

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

low air drag, was tested for water resistance, trimming moment, and draft over a range of speeds and loads at fixed trims. The four hulls had straight V-bottoms, and the effect of hollowing the planing bottom to a more conventional form was determined on one hull. The time and distance to take-off at a common all-up weight of 30,000 pounds were calculated for the five hulls and also for three American hulls of different beams. The effect of beam on the air drag has been measured in a wind tunnel. The volume back to the rear step has been noted.

When hulls of the same length carrying the same load are considered, narrow hulls on the whole offer less resistance, being better at low speeds and when planing, though worse at the hump. The narrow hulls, however, are more deeply immersed and less seaworthy. In order to insure equal seaworthiness, when a given load is carried, decreased beam must be accompanied by increased length. This arrangement partly offsets the advantage in resistance so that the take-off of narrow hulls is only slightly shorter, and little is to be gained by increasing the length-beam ratio beyond 8.5.

In order to give approximately the same seaworthiness for each model hull, the draft at the step, expressed as a proportion of the length of the forebody, was taken as the criterion.

A more marked advantage for narrow hulls was obtained from the American hulls but the range of length-beam ratio covered (5.3 to 6.0) was too small to allow conclusions to be drawn about very narrow hulls.

The hull with hollow V-sections has the same take-off as the straight V-section hull of the same beam. It is cleaner running on the water, but the air drag is increased by 5 percent.

The air drag reaches a minimum between length-beam ratios 9 and 10.

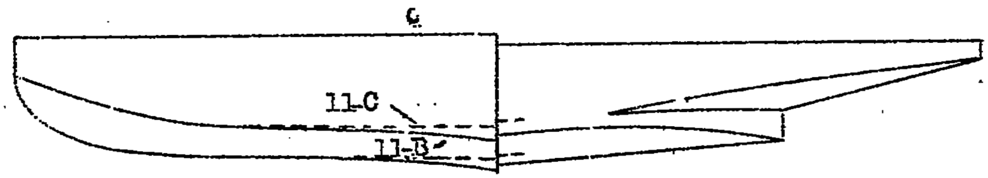
The accommodation volume falls off rapidly between length-beam ratios 5.5 and 7, after which it decreases much more slowly.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

187. Parkinson, J. B.: Tank Tests of a Model of a Flying-Boat Hull Having a Longitudinally Concave Planing Bottom. NACA TM No. 545, 1935.

The NACA model 11-B, which has a longitudinally concave planing bottom forward of the step, was tested in Langley tank no. 1 over a wide range of loadings. The results of the tests are presented as curves of resistance and trimming moment plotted against speed for various trims and as curves of best trim and resistance and trimming-moment coefficients at best trim plotted against speed coefficient. The characteristics of the form at the optimum trim are compared with those of NACA model 11-C, which has the same form with the exception of a planing bottom longitudinally straight near the step. Photographs of the models being towed in the tank are included for a comparison of the spray patterns. A discussion of possible effects on longitudinal stability is included.

At the best trim in each case, model 11-B has lower resistance at high speeds, a higher maximum positive trimming moment near the hump speed, and a more favorable spray pattern than that of model 11-C. The decrease in resistance at high speeds is partly attributed to the effective increase in angle of afterbody keel near the step. This increase would tend to increase the aerodynamic drag.




188. Dawson, John R.: Tank Tests of a Model of a Flying Boat Hull with a Fluted Bottom. NACA TN No. 522, 1935.

A $\frac{1}{5}$-size model of a flying-boat hull having flutes in the bottom both forward and aft of the step (NACA tank model 19) was tested in Langley tank no. 1 to determine its water performance. The model was also tested after the successive removal of the flutes on the afterbody and forebody. The results from these tests are compared with those from tests of a model of the hull of the Navy PN-8 flying boat and it is

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

concluded that the fluted-bottom model and all its modifications are inferior to the model of the PN-8.

189. Allison, John M.: Tank Tests of a Model of One Hull of the Savoia S-55-X Flying Boat - N.A.C.A. Model 46. NACA TN No. 635, 1938.

A general resistance test was made in Langley tank no. 1 of one of the twin hulls of the Italian Savoia S-55-X flying boat. The data are given in nondimensional form to facilitate their use in applying this form of hull to any other flying boat or comparing its performance with the performance of other hulls. The results show that the resistance characteristics at best trim of this model are excellent throughout the speed range although excessively large maximum positive trimming moments were observed. The Savoia S-55-X at normal loads was exceptionally clean-running at all speeds.

The performance of the S-55-X hull was compared with that of NACA model 35 by means of a take-off calculation for a twin-hull, 23,500-pound flying boat. The calculation shows that the S-55-X hull has better take-off performance. It is possible that the improvement in resistance can be attributed to the very low negative dead rise of the planing bottom.

190. Allison, John M.: Tank Tests of a Model of the Hull of the Navy PB-1 Flying Boat - N.A.C.A. Model 52. NACA TN No. 576, 1936.

General fixed-trim and free-to-trim resistance tests were made in Langley tank no. 1 of a model of the hull of the Navy PB-1 flying boat. A specific free-to-trim resistance test was also made with scale design load and take-off speed. The tests were made as part of a program to provide information on the water performance of flying-boat hulls of early design for which hydrodynamic data have heretofore been unavailable.

The resistance obtained from the fixed-trim test was found to be about the same as that of the model of the NC flying-boat hull and greater at the hump but smaller at high speeds than that of a model of the Sikorsky S-40 flying-boat hull.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

191. Bell, Joe W.: Tank Tests of a Model of the NC Flying-Boat Hull - N.A.C.A. Model 44. NACA TN No. 566, May 1936.

A general fixed-trim resistance test and a specific free-to-trim resistance test were made of a $\frac{1}{7.06}$-size model of the NC-type hull in Langley tank no. 1. The results of the tests are given in curves plotted as nondimensional coefficients and are compared with the test results of NACA model 11-A.

The NC model (NACA model 44) shows higher resistance than model 11-A at hump speed but lower resistance at high speeds. Model 44 has a higher best trim at the hump and a lower maximum positive trimming moment than model 11-A. At high speeds the best trim and the trimming moments of the two models are approximately the same.

192. Parkinson, John B.: Tank Tests of Auxiliary Vanes as a Substitute for Planing Area. NACA TN No. 490, 1934.

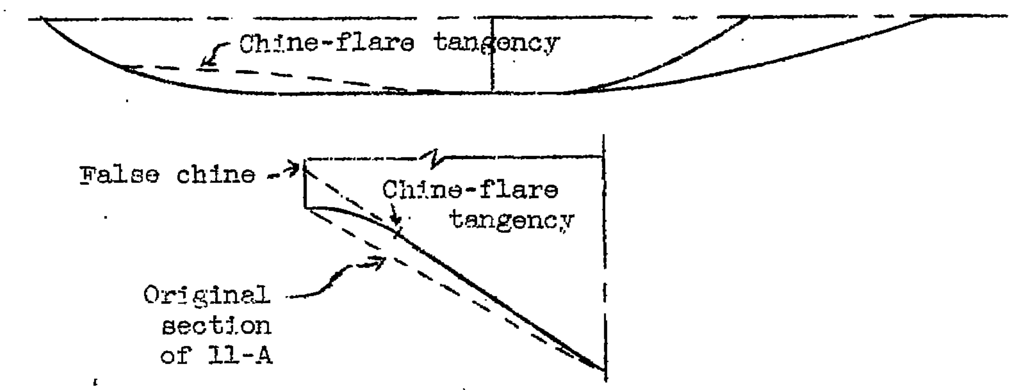
Resistance tests were made of two models of flying-boat hulls. The first model represents the hull of the U.S. Navy PN-8 flying boat and the second model represents a proposed alteration of the PN-8, in which the sponsons of the original hull are removed and auxiliary lifting vanes (hydrofoils) are fitted at the chines immediately forward of the main step. The tests showed that the altered form gave a large increase in hump resistance and a very undesirable spray formation through a large part of the speed range.

193. Parkinson, J. B.: Tank Tests of Model 11-G Flying-Boat Hull. NACA TN No. 531, 1935.

The NACA model 11-G flying-boat hull, a modification of NACA model 11-A, was tested in Langley tank no. 1 over a wide range of loadings. The planing bottom of model 11-G has a variable-radius flare, or concavity, at the chines in contrast to the straight V planing bottom of model 11-A. The results are given as curves of resistance and trimming moment plotted against speed for various trims. The characteristics of the form at the optimum trims are given in nondimensional form as curves of resistance coefficient, best trim, and trimming-moment coefficient plotted against speed coefficient.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

As compared with the original form, model 11-G is shown to have higher resistance at all loads and speeds and higher maximum trimming moments at heavy loads. The spray pattern, however, is generally more favorable, indicating that the service performance of model 11-A would be improved by some form of chine flare.




194. Allison, John M.: Tank Tests of Model 36 Flying-Boat Hull. NACA TN No. 638, 1938.

NACA model 36, a hull form with parallel middle body for half the length of the forebody and designed particularly for use with stub wings, was tested over a range of practical load, trim, and speed to determine the general resistance characteristics of the form. It was also tested free to trim with the center of gravity at two locations. The results are given in the form of nondimensional coefficients.

The resistance at the hump was exceptionally low but, at high planing speeds, afterbody interference made the performance only mediocre.

195. Parkinson, J. B.: Tank Tests of Models of Floats for Single-Float Seaplanes - First Series. NACA TN No. 563, 1936.

Large models of the Mark V and Mark VI floats used by the Bureau of Aeronautics, Navy Department, for single-float seaplanes (NACA models 41-A and 41-B, respectively) were tested in Langley tank no. 1

to provide resistance data for typical single floats and a basis for possible improvements of their form. The tests were made at fixed trims over a wide range of possible loadings and also with the models free to trim at the design load. NACA model 35-B, a pointed-step hull that might be suitable for the same service, was tested free to trim with the same load and position of the center of gravity as used in tests of the Mark V and Mark VI floats.

The resistance of model 41-B was greater than that of model 41-A either when free to trim or at the best trim for each. The resistance of model 35-B was less than either of the other models at the hump speed, greater at intermediate planing speeds, and less at the speeds and loads near get-away, although the spray was generally worse owing to the absence of transverse flare.

The trims assumed by models 41-A and 41-B, when tested free to trim, were found to be excessive at the hump speed. The corresponding trim of model 35-B was found to be approximately 3° lower because of the lower angle of afterbody keel used in this model, and the maximum hump resistance was 15 percent lower. A small hydrofoil fitted at the second step of model 41-A reduced the maximum trim about 2° and the maximum resistance 9 percent.

At speeds slightly below the point where the chines became dry, the flow over the rounded afterdecks of models 41-A and 41-B gave rise to an undesirable yawing and skidding tendency. No mention of this tendency was made, however, in the reports of service trials on a full-scale installation.

196. Allison, John M., and Ward, Kenneth E.: Tank Tests of Models of Flying Boat Hulls Having Longitudinal Steps. NACA TN No. 574, 1936.

Four models with longitudinal steps on the forebody were developed by modification of a model of a conventional hull and were tested in Langley tank no. 1. The same afterbody, of the usual V-section, was used with all the forebodies and the depth of the transverse step at the keel was the same in all cases. Two models had two longitudinal steps on each side, one with constant dead rise and depth of step, the other with varying dead rises between steps and different depths of steps. The other two models each had one longitudinal step and were derived from the second of the two-step models by eliminating first the inboard and then the outboard step alternatively.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

The models with longitudinal steps were found to have smaller resistance at high speed and greater resistance at low speed than the parent model that had the same afterbody but a conventional V-section forebody. The models with a single longitudinal step had better performance at hump speed and as low high-speed resistance except at very light loads.

Spray strips at angles from 0° to 45° to the horizontal were fitted at the longitudinal steps and at the chine on one of the two-step models having two longitudinal steps. The resistance and height of the spray were less with each of the spray strips than without; the most favorable angle was found to lie between 15° and 30°. Spray strips of two different widths (0.020 and 0.007 beam) were fitted and it was found that the resistance was slightly greater with the narrower strip. Eliminating the spray strip on the outboard step was found to decrease but little the effectiveness of the combination. In still another phase of the investigation the inboard- and outboard-step spray strips were shortened without adding appreciably to the resistance or the height of the bow wave.

General form of steps

197. Parkinson, John B., and Dawson, John R.: Tank Tests of N.A.C.A. Model 40 Series of Hulls for Small Flying Boats and Amphibians. NACA Rep. No. 543, 1936.

The NACA model 40 series of flying-boat hull models consists of two forebodies and three afterbodies combined to provide several forms suitable for use in small marine aircraft. One forebody is of the usual form with hollow bow sections and the other has a bottom surface that is completely developable from bow to step. The afterbodies include a short pointed afterbody with an extension for the tail surfaces, a long afterbody similar to that of a seaplane float but long enough to carry the tail surfaces, and a third obtained by fitting a second step in the latter afterbody.

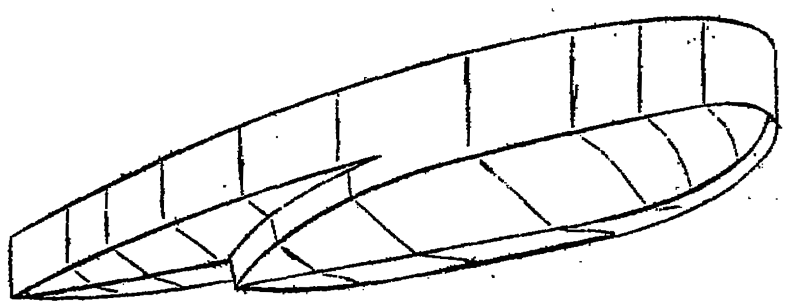
General resistance tests were made in Langley tank no. 1 of various combinations over a suitable range of loadings. Fixed-trim tests were made for all speeds likely to be used and free-to-trim tests were made at low speeds to slightly beyond the hump speed. The characteristics of the hulls at best trim have been deduced from the data of the tests at fixed trim and are given in the form of nondimensional coefficients applicable to any size of hull.

Comparisons among the forms are shown by suitable cross plots of the nondimensional data and by photographs of the spray patterns. The difference between the results obtained with the two forebodies was small for the smooth-water conditions simulated in the tank. With the same forebody in each case, the resistance of the no-step afterbody was least at the hump speed and that of the pointed afterbody was least at high speeds.

Take-off examples of an 8000-pound flying boat or amphibian having a power loading of 13.3 pounds per horsepower and a 2000-pound flying boat having a power loading of 18.2 pounds per horsepower are included to illustrate the application of the data.

198. Dawson, John R.: Tank Tests of Three Models of Flying-Boat Hulls of the Pointed-Step Type with Different Angles of Dead Rise - N.A.C.A. Model 35 Series. NACA TN No. 551, 1936.

The results of resistance tests made in Langley tank no. 1 of three models of flying-boat hulls of the pointed-step type with different angles of dead rise are given in charts and are compared



HYDRODYNAMICS
Steady Longitudinal Forces and Moments

with results from tests of more conventional hulls. Increasing the angle of dead rise from 15° to 25° had little effect on the hump resistance, increased the resistance throughout the planing range, increased the best trim, reduced the maximum positive trimming moment required to obtain best trim, and had but a slight effect on the spray characteristics. For approximately the same angles of dead rise the resistances of the pointed-step hulls were considerably lower at high speeds than those of the more conventional hulls.

199. Herrmann, H., Kempf, G., and Kloess, H.: Tank Tests of Twin Seaplane Floats. NACA TM No. 486, 1928.

The available information on twin seaplane floats is presented in a discussion based upon numerous model tests in the HSVA tank (Hamburg) and some full-scale tests on the Starnberg lake. The various topics include (1) scale effect, (2) shape of planing bottom (essentially dead rise), (3) shape of the step, (4) determination of distance between floats, (5) maneuverability, and (6) spray. A description of the method of plotting resistance data is also presented and explained.

200. Bell, Joe W.: Tank Tests of Two Floats for High-Speed Seaplanes. NACA TN No. 473, 1933.

Results are presented of resistance tests of $\frac{1}{4}$-size models of two floats for high-speed seaplanes. One float was similar to that used on the Macchi high-speed seaplane which competed in the 1926 International Schneider Cup races, and the other float was designed at Langley tank no. 1 to improve the water performance of the Macchi float. The model designed at Langley tank no. 1 showed considerably better water performance than the model of the Macchi float.

201. Dawson, John R.: Tank Tests of Two Models of Flying-Boat Hulls to Determine the Effect of Ventilating the Step. NACA TN No. 594, 1937.

The results of resistance tests made in Langley tank no. 1 on two models of flying-boat hulls to determine the effect of ventilating the step are given graphically. The step of NACA model 11-C was

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

ventilated in several different ways and it was found that the resistance of the normal form is not appreciably affected by artificial ventilation in any of the forms tried. Further tests made with the depth of the step of model 11-C reduced likewise show no appreciable effect on the resistance from ventilation of the step. Tests were made on a model of the hull of the Navy P3M-1 flying-boat hull both with and without ventilation of the step. It was found that the discontinuity which is obtained in the resistance curves of this model is eliminated by ventilating the step.

202. Anon.: Tank Tests on a Faired Main Step for the Short R.2/33 (Sunderland) Flying Boat. Rep. No. B.A. 1472, British R.A.E., April 1938.

Tests were required on a fairing designed to increase the top speed without hampering the take-off. Resistance and moments were measured with and without the fairing over a range of speed up to the take-off at both normal and overload all-up weights of 44,600 pounds and 49,000 pounds, respectively. The porpoising characteristics were observed for take-off and alighting at normal load.

The fairing slightly increased the resistance at the hump and just before take-off and reduced it elsewhere. The effect on the time and distance to take-off at the normal load was negligible. The trimming moments were very little altered. For porpoising, the upper limit of stability was reduced 1° for the take-off but was still satisfactory; otherwise there was no appreciable change.

203. Bell, Joe W., and Olson, Roland E.: Tank Tests to Determine the Effects of the Chine Flare of a Flying-Boat Hull - N.A.C.A. Model Series 62 and 69. NACA TN No. 725, 1939.

Twenty-two models of flying-boat hulls were tested in Langley tank no. 1 for the purpose of determining the effects on water resistance and spray of 13 variations in the transverse section of the bottom of the forebody and of three variations in the form of the afterbody. The forebodies were of the same over-all dimensions and differed in the type and amount of chine flare. The afterbodies included one with a pointed plan form and straight buttocks, one with a second step and straight buttocks, and one with a second step and concave buttocks. The depth of the step at the keel was the same in all models.

In general, the effect of chine flare on the resistance was small although, at speeds just above the hump, the resistance of forms with chine flare was generally less than the resistance of the form without chine flare. The chine flare reduced the height of the forward part of the spray where the spray left the chine of the model above the water level but had little effect on the spray where the chine of the model was below the water level. In cases of extreme flare, the spray forming just ahead of the step seemed to be higher.

It was concluded that NACA model 62-AD, consisting of a forebody with a chine flare having a width of 0.083 beam and 5° angle, combined with an afterbody having a second transverse step and concave buttocks, was the best of the combinations tested. Charts for the determination of the resistance and the static properties of this model are given.

204. Mitchell, R. J.: Tank Tests with Seaplane Models. Aircraft Engineering, vol. II, no. 20, Oct. 1930, pp. 255-259.

A general outline and a theoretical basis for model tests are presented. Racing seaplanes S.5 and S.6 are introduced and the results of certain modifications on the hull forms and arrangements are discussed. Considerable emphasis is placed on problems regarding lateral stabilization.

The addition of chine strips to the forebody was found to decrease the water resistance but to increase the air drag of the float about 10 percent.

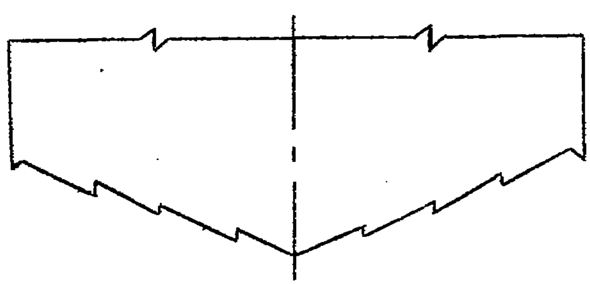
A twin-float seaplane was tested with two different widths of track; the wider track gave much lower resistance. The high engine torque inherent in racing seaplanes created such an eccentricity of loading that for satisfactory spray characteristics and lateral stability it was found necessary to make one float longer than the other and to place it farther away from the center line of the seaplane.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

Stub-wing stabilizers were found to present bad dynamic characteristics when the angle of heel exceeded 6°. Several different forms were tested but the best solution seemed to be the addition of small wedge-shaped pieces to the tips of the existing stabilizers at the step and a small hydrofoil attached to the end of the stabilizer.

205. Clement, Eugene P., and Morewitz, Alvin H.: Tests of a Model of a Flying-Boat Hull Incorporating the Pigeon-Snadecki Type Longitudinal Steps - NACA Model 162. NACA MR No. L5B10a, Bur. Aero., 1945.

Tests were made of a model of a flying-boat hull incorporating the Pigeon-Snadecki type longitudinal steps on the forebody (NACA model 162) and of a modified form having the longitudinal steps on both forebody and afterbody (NACA model 162-A). Both forms were of unconventional design and their performance was found to be inadequate to justify more than very brief testing. Curves of resistance and trim are presented from the free-to-trim tests of model 162-A and curves of resistance and trimming moment from tests of fixed trims of 5° and 7°. Spray photographs of model 162-A are also presented for both free-to-trim and fixed-trim conditions. It was concluded that neither form would be suitable for use as a flying-boat hull. The behavior of the models was so unsatisfactory that it was not possible to evaluate from these tests the hydrodynamic characteristics of the Pigeon-Snadecki type longitudinal steps.



General form of steps

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

206. Truscott, Starr: Tests of a Model of Hull of Kreider-Reisner Amphibian Flying Boat, Type XA-942. NACA MR, Jan. 10, 1934.

Specific fixed-trim and free-to-trim resistance tests were made of a $\frac{1}{3}$-size model of the Fairchild Amphibian flying-boat hull. The first tests were made of a single forebody with two different afterbodies; one was pointed, the other had a full second step. Because of the inferior performance of both these forms, a new forebody fitted with spray strips set under the chines was used in conjunction with the two original afterbodies. The new forebody reduced the free-to-trim resistance at the hump and decreased the trim at which the hump occurred. The data are summarized, tabulated, and plotted. Photographs showing the spray produced by the model while under way are included.

207. Truscott, Starr: Tests of Model of Edo Float No. 37-15750. NACA MR, July 3, 1934.

Specific fixed-trim and free-to-trim resistance tests were made of a $\frac{1}{4}$-size model of one float (Edo float no. 37-15750) of a twin-float seaplane. The model was of the Edo fluted-bottom type and was fitted with spray strips that extended the full length of the chine on both forebody and afterbody. The data are presented in the form of tables and curves. Photographs taken to show the spray formation are included.

208. Shoemaker, James M.: Tests of Model of Edo Float No. 38-3430. NACA MR, May 4, 1934.

Specific fixed-trim and free-to-trim resistance tests were made of a $\frac{1}{3}$-size model of a seaplane float (Edo float no. 38-3430). The model was of the Edo fluted-bottom type and was fitted with spray strips that extended the full length of the chine on both forebody and afterbody. The data are presented in the form of tables and curves. Photographs taken to show the spray formation are included.

HYDRODYNAMICS
Steady Longitudinal Forces and Moments

209. Truscott, Starr: Tests of Model of Edo Float Type XT. NACA MR, Rep. No. S-2, Dec. 23, 1932.

Specific fixed-trim and free-to-trim resistance tests were made of a $\frac{1}{4}$-full-size model of one float (Edo float type XT) of a twin-float arrangement designed for use under a Curtiss "Condor." The tests were made to determine the suitability of the design for this purpose. The model was towed from a point corresponding to the height of the center of gravity of the complete airplane. The data are given in the form of tables and curves. Photographs of the model under way at various speeds and trims are included.

210. Truscott, Starr: Tests of Model of Edo Hull for Courtney Amphibian Flying Boat. NACA MR, May 26, 1933.

Specific fixed-trim resistance tests were made of a fluted-bottom hull proposed for use as an amphibian. The wheels for land use were arranged with one wheel projecting through an opening in the bottom some distance aft of the bow and with two wheels on retracting gear farther aft. The data are summarized, tabulated, and plotted. Photographs of the model under way showing the spray and the position of the projecting forward wheel relative to the water are included.

211. Truscott, Starr: Tests of Model of Edo Hull for Twin-Float Seaplane. NACA MR, Sept. 28, 1933.

Specific fixed-trim resistance tests were made of a $\frac{1}{4}$-size model of one float of a twin-float seaplane. The data are tabulated and plotted. Photographs showing the spray produced by the model while under way are included.

212. Truscott, Starr: Tests of Model of Glenn L. Martin Company Flying-Boat Hull - Model No. 130. NACA MR, March 22, 1933.

Tests were made of a $\frac{1}{8}$-size model of a flying-boat hull, Glenn L. Martin Co. model no. 130, to obtain information regarding the performance of the model on the water. The hull was fitted with stub wings that were unusual in that the lower surfaces sloped upward toward the tips in a manner to prolong the vee of the bottom. The stub wings had a step that originated at the hull abreast of the main step and raked aft with a gradual decrease of depth until it disappeared at the tip of the stub.

Specific fixed-trim and free-to-trim resistance tests were made at numerous conditions of trim, speed, and load and on different modifications to the original design. Low-speed tests were made of the model running free to trim astern. Static transverse stability tests were made at several gross loads.

The data are tabulated and plotted. Numerous photographs of the model under way are included.

213. Truscott, Starr: Tests of Model of Hull of Douglas Amphibian YO-44. Supplementary Report. NACA MR, May 16, 1933.

Specific fixed-trim and free-to-trim resistance tests were conducted on a $\frac{1}{12}$-size and a $\frac{1}{6}$-size model of a hull intended for use on a large amphibian (Douglas YO-44). Several modifications designed to improve the water performance were also investigated. The data are summarized and plotted. Numerous photographs of the models under way are included.

(See also abstracts 16, 34, 40, 44, 45, 46, 83, 84, 107, 117, 118, 120, 235, 252, 257, 273, 280, 281, 285, 290, 308, 309, 310, 312, 313, 321, 322, 323, 327, 356, 375, 381, 382, and 385.)

## Steady Longitudinal Forces and Moments - Resistance

214. Truscott, Starr, and Parkinson, J. B.: The Increase in Frictional Resistance Caused by Various Types of Rivet Heads as Determined by Tests of Planing Surfaces. NACA TN No. 648, 1938.

The increase in the frictional resistance of a surface caused by the presence of rivet heads was determined by towing four planing surfaces of the same dimensions in Langley tank no. 1. One surface was smooth and represented a surface without rivet heads or one with perfectly flush countersunk rivets. The other three surfaces were each fitted with the same number of full-size rivet heads but of a different type arranged in the same pattern on each surface. The surfaces were towed at speeds representative of the high water speeds encountered by seaplanes during take-off and the range of Reynolds number covered by the tests was from $4 \times 10^6$ to $13 \times 10^6$.

The rivet heads investigated were oval countersunk, brazier, and round, for rivets having shanks 5/32 inch in diameter. The oval countersunk heads were sunk below the surface by dimpling the plating around them.

The results of the tests showed that, for the rivet heads investigated, the increase in the friction coefficient of the surface is directly proportional to the height of the rivet head. The order of merit in regard to low resistance was found to be: flush countersunk, oval countersunk (whether sunk below the surface or not), brazier, and round.

215. Parkinson, J. B.: Tank Tests to Show the Effect of Rivet Heads on the Water Performance of a Seaplane Float. NACA TN No. 657, 1938.

A $\frac{1}{3.5}$-size model of a seaplane float constructed from lines drawings supplied by the Bureau of Aeronautics, Navy Department, was tested in Langley tank no. 1, first with smooth painted bottom surfaces and then with roundhead rivets, plate laps, and keels fitted to simulate the bottom of a metal float. The increase in water resistance caused by the added roughness was found to be from 5 to 20 percent at the hump speed and from 15 to 40 percent at high speeds. The effect of the roughness of the afterbody was found to be negligible except at high trims.

The model data were converted to apply to full-scale conditions by the usual method which assumes that the forces vary according to Froude's law and, in the case of a smooth model, by a method of separation that takes into account the effect of scale on the frictional resistance. The tests indicated that the effect of rivet heads on the take-off performance of a relatively high-powered float seaplane is of little consequence but that the effect may be of greater importance in the case of more moderately powered float seaplanes.

(See also abstracts 383 and 401.)

## Steady Longitudinal Forces and Moments - Moment

216. Bell, Joe W., and Havens, Robert F.: Tank Tests of a 1/3-Size Dynamic Model of the PB2Y-3 Airplane with Simulated Jet Motors - NACA Models 131J, 131J-1, and 131J-2. NACA MR, Bur. Aero., June 8, 1943.

This investigation was undertaken for the purpose of determining the effect of rocket motors upon the longitudinal stability of the Consolidated PB2Y-3 flying boat at a gross load of 76,000 pounds. Three air nozzles, used to simulate the rocket motors, were installed on the powered dynamic model at the sternpost. Various positions and angles of the rockets were tested and in each case the trim at the hump was reduced. This reduction in hump trim caused by the exhaust under the tail extension of the model indicated that even larger effects would result if the rockets were located in the main step and permitted to exhaust under the afterbody.

With the line of thrust of the rockets below the center of gravity, positive trimming moments were produced at planing speeds and the limits of stable positions of the center of gravity were moved forward. No significant change in the limits was noticed when the thrust line of the rockets was made to pass through the center of gravity.

HYDRODYNAMICS
Unsteady Longitudinal Forces and Moments

217. Carroll, Thomas: A Dangerous Seaplane Landing Condition. NACA TN No. 287, 1928.

A peculiar phenomenon in seaplane landing is observed and reported. The seaplane having executed a normal fast landing at low incidence, a forward movement of the control stick effected an unusual condition in that the seaplane left the water suddenly in an abnormal attitude. The observations describing this phenomenon are offered as a warning against possible accident and as a conjectural cause of seaplane landing accidents of a certain kind.

218. Shaw, R. A., Smith, A. G., Morris, W., and Evens, G. J.: An Investigation of the Water Performance of the Sunderland Flying Boat. Rep. No. H/Res/136, British M.A.E.E., Jan. 8, 1940.

Tests were made at the Marine Aircraft Experimental Establishment of the water performance of the Short Sunderland flying boat to provide full-scale data for comparison with tank tests of the model. Measurements of attitude, acceleration, and speed were made in take-offs, landings, and accelerated and steady taxying runs. The effect of elevators, flaps, and wind on attitude is pointed out. The instrumentation and testing technique are discussed in detail. Enlargements of gyro-film records that show the variation of attitude and vertical acceleration with time for typical porpoising conditions are included.

The drag of the Sunderland flying boat has been calculated from observed accelerations and from an estimate of the thrust and has been found to be less in landing than in take-off at the same attitude. The difference is greatest at the hump where drag during take-off is 60 percent greater than drag during landing. The differences in drag diminish at higher speeds until substantial agreement is reached at 65 knots. As corrections for slipstream effects are not sufficient to explain the increases in drag, the acceleration appears to be the influencing factor.

219. Abel, G. C.: Measurements of Accelerations at Different Parts of a Boat Seaplane during Take-Off and Landing. R. & M. No. 1829, British A.R.C., 1938.

Reasons for inquiry.- Measurements of acceleration at selected parts of a seaplane structure during take-off and landing were required to provide further knowledge of structure loads.

HYDRODYNAMICS
Unsteady Longitudinal Forces and Moments

Range of investigation.- Take-offs and landings were made in calm and choppy water. The landings were made deliberately heavy in order to give an upper limit to the factors required on seaplane structures.

The normal acceleration was measured at seven positions and the longitudinal acceleration at two of these positions. At one position four accelerometers of different frequencies were fitted. A gyro pitch recorder was fitted to record the change of attitude during impact and from this record the angular acceleration has been deduced.

Conclusions.- The maximum normal accelerations recorded were 2g in take-off and 4.5g (in bow and center section) in a stalled landing.

The maximum angular acceleration was $1\frac{1}{2}$ radians per second per second, the maximum difference between bow and tail accelerations was 1.6g and the maximum difference between hull and center section was 0.9g. In some landings the correction for angular acceleration was insufficient to bring the bow and tail accelerations to the same value as the acceleration amidships and this shows that the hull distorts. In the majority of landings there was a distortion of the center section similar to that recorded on a Singapore IIc seaplane when dropped into water.

The records from the four accelerometers of different frequencies showed good agreement. The higher frequency instruments gave more oscillatory records, were less easily analyzed, and gave only a small increase in accuracy.

220. Richardson, H. C.: The Reaction on a Float Bottom When Making Contact with Water at High Speeds. NACA TN No. 288, 1928.

A dangerous seaplane landing condition (abstract 217), which occurred at high speeds and low attitudes and which resulted in pitching forward suddenly and then bouncing uncontrollably out of the water at an unfavorable attitude, has been explained. An initial suction combined with down elevator started rotation and threw the bow deep. The displacement, which increased suddenly, in combination with added lift on the elevators supplied the necessary lift for the bounce before the rotation could be checked. This analysis was affirmed by Model Basin tests made at the Washington Navy Yard and reported in the appendix.

221. Verduzio, Rudolfo: Stresses Developed in Seaplanes While Taking Off and Landing. NACA TM No. 677, 1932.

Theoretical and experimental results of 18 different references on hydrodynamic loads are reviewed and compared. Correlation and analysis were carried out to arrive at general conclusions regarding the influence of angle of dead rise, elasticity of the structure, weight of the seaplane, and distribution of loads on the bottom of the seaplane during operations in calm water and in rough water.

(See also abstracts 236, 237, and 239.)

## Unsteady Longitudinal Forces and Moments - Resistance

222. Shaw, R. A.: The Effect of Acceleration on the Drag of the Sunderland Hull. Rep. No. H/Res/136.A., British M.A.E.E., Oct. 1, 1940.

An effect of acceleration on hull resistance has been found from a comparison of the resistance of the Sunderland in take-offs, steady runs, and landings deduced from estimates of the thrust and measurements of the acceleration. The test results have been reduced to hull water resistance at the same speed, attitude, and load on the water. The conditions chosen have been those for the measured take-offs, that is, flap neutral, weight of 43,000 pounds, wind of 9 knots, and elevator neutral. (The only remaining factor in the comparison is therefore the acceleration.) The water resistance for take-offs, steady runs, and landings has been compared with the model resistance.

HYDRODYNAMICS
Unsteady Longitudinal Forces and Moments - Resistance

The full-scale hull resistance in steady runs was in fair agreement with the model resistance that was also measured at constant speed. The full-scale resistance in take-off, when the acceleration averaged 0.11g, was about 30 percent higher from 20 to 50 knots. The resistance in landing, when the deceleration was about 0.13g, was 30 to 40 percent lower than the steady-run resistance over the same speed range.

Unsteady Longitudinal Forces and Moments - Lift

223. Jones, E. T., and Blundell, R. W.: Force and Pressure Measurements on V-Shapes on Impact with Water Compared with Theory and Seaplane Alighting Results. Rep. No. F/Res/107, British M.A.E.E., Jan. 28, 1938.

Introductory.- Measurements of pressure and total impact force on a V-shape and on seaplane hulls have been made, and it was desirable that further tests be made and the complete results compared with the impact theory.

Range of investigation.-

Part I. The pressure measurements described in MAEE report F/Res/78[1] have been extended to include the effect of translational velocity and further measurements of impact force have been made.

Part II. The experimental results from Part I are compared with full-scale work.

Part III. Results of Wagner's theory of impact forces are compared with the experimental results.

Conclusions.-

(1) The measured peak pressure at any point on a V-shape with straight sides is related to the impact conditions by the empirical law

$$p_{max} = \frac{V^2{}_n}{K} \cot \phi$$

where $\cos \phi = \cos \theta \quad \cos \alpha$

$180^\circ - 2\theta$ = contained angle of V-shape

$\alpha$ = angle of incidence at impact

$V_n$ = velocity normal to the keel

and K is a constant dependent to a small extent on the loading.

(2) The above law has been applied to alighting impact conditions of the Southampton and Perth seaplanes and to the vertical impact tests on the Singapore IIc. and very good agreement with the measured pressures is shown in all cases. Since the planing bottoms of two of these seaplanes are curved in transverse section, there is evidence that the law applies to V-shapes with curved as well as straight sides.

(3) The peak pressure at any point on a V-shape calculated by Wagner's theory of impacts exceeds the measured peak pressure, though the mean pressure over the section immersed at any time agrees well with the measured mean. Theory shows that the peak pressure occurs at, or very close to, the boundary of the pressure surface so that the discrepancy between calculated and measured pressures is partly due to the comparatively large diameter of the diaphragm used in the measurements, over which the average pressure only is registered.

(4) The peak force of impact over a V-shape agrees well with that calculated by Wagner's theory.

(5) Theory and experiment agree in showing that a hull with a slightly less transverse curvature than that of the Singapore IIc. would have a constant peak pressure between keel and chine.

(6) Theory and experiment agree in showing that the maximum force of impact occurs at a constant immersion, irrespective of the striking velocity. They also agree in showing that for this immersion the chines of a modern boat seaplane are well clear of the water, hence a reduction of beam on modern practice would not occasion an increase in normal force on alightings.

224. Bottomley, G. H.: The Impact of a Model Seaplane Float on Water. Eighteenth Series. R. & M. No. 583, British A.C.A., 1919.

Tests of three models of seaplane floats were made at the William Froude National Tank to determine the impact received by a

HYDRODYNAMICS
Unsteady Longitudinal Forces and Moments - Lift

seaplane landing on the water and the variation of impact with shape of bottom, trim, horizontal speed, and vertical speed. The three models had the same afterbody and forebodies having flat, straight V, and curved V cross sections. The models were allowed to drop at fixed trim, a time history of the vertical position was recorded, and the maximum impact was obtained by taking the product of the dropping mass and the maximum vertical deceleration.

It was found that: the flat-bottom float had a greater impact than either of the V-bottom floats; the straight V-bottom float had a slightly smaller impact than the curved V-bottom float; increasing either the horizontal speed or the flight-path angle increased the impact; and increasing the trim decreased the impact, especially at trims such that the afterbody hit the water first. The results of the tests have been reduced to an equation with an empirical constant that depends on the trim and the shape of the bottom.

225. Richardson, E. G.: Impact on Water: A Summary. Rep. No. H/Arm/Res. 24, British M.A.E.E., Jan. 4, 1945.

Research on the impact of solids on water has been briefly summarized and the contribution of each item of research has been outlined. The theoretical work has been covered by von Kármán, Pabst, Wagner, and Kreps. Experimental work has been done at the Marine Aircraft Experimental Establishment and the Royal Aircraft Establishment and at the Okechi Research Laboratory by Watenabe.

226. Pabst, Wilhelm: Landing Impact of Seaplanes. NACA TM No. 624, 1931.

The theory of the landing impact is briefly stated and the applicability of a previously suggested formula is extended. Theoretical considerations regarding impact measurements of models and actual seaplanes are followed by a brief description of the instruments used in actual flight tests. The report contains a description of the strength conditions and deals exhaustively with force measurements on the float gear of a Heinkel HE 9a monoplane with flat-bottom and with V-bottom floats. The experimental data are given and compared with the theoretical results. In general, the numerical agreement is satisfactory, except for the influence of the angle of dead rise, which is underestimated by the load assumptions of the DVL and overestimated by the theory. Several calculations are corrected on the basis of the tests. Stress measurements on float gear struts, bottom-pressure measurements on an HE 5 float, and deflection measurements on the bottom of a flying boat are also mentioned. The agreement between theory and practice is found to be good in the present tests, as well as in earlier American tests. Attention is called to the importance of seaway measurements and airplane vibration tests. Inertia coefficients are suggested for the development of landing-impact safety factors.

227. Jones, E. T., Douglas, G., Stafford, C. E., and Cushing, R. K.: Measurements of Acceleration and Water Pressure on a Seaplane When Dropped into Water. R. & M. No. 1807, British A.R.C., 1937.

Reasons for inquiry.- Measurements of the acceleration and water pressure on a boat seaplane when dropped into water with zero forward speed were required for comparison with measurements made during take-off and landing.

Range of investigation.- The seaplane was dropped from a crane into the sea from graded heights up to 18 feet and the acceleration measured in the hull and different parts of the structure. The water pressure over one transverse section of the hull bottom was also measured and the seaplane was inspected after each impact for failures in the structure.

Conclusions.- It should be noted with the conclusions that the seaplane under test had finished a normal service career.

At the maximum impact velocity (27.5 ft/sec) of the tests the normal acceleration was 9g, the maximum intensity of pressure 34 pounds per square inch, the maximum force per inch length of hull over a transverse section slightly ahead of the step was 2400 pounds, and the mean pressure over this section at the time of maximum force was 17 pounds per square inch.

Superficial failures in the structure were identified at 4.1g, major failures at 4.6g, and buckling of the hull side at 4.6g. On the other hand, there was no sign of distortion or failure of the planing bottom at the end of the tests.

The pressure results could have been predicted with good accuracy from M.A.E.E. Report F/Res/78[2] on "Some Measurements of Pressure over a V Shape When Dropped into Water." By coincidence the most severe test produced pressure results of about the same magnitude as the most severe landings in abstract 236, but a comparison of these data shows that the pressure given on landing depends little on the vertical velocity at impact but mostly on the forward speed and attitude.

228. Batterson, Sidney A.: The NACA Impact Basin and Water Landing Tests of a Float Model at Various Velocities and Weights. NACA ACR No. L4H15, 1944.

The first data obtained in the United States under the controlled testing conditions necessary for establishing relationships among the numerous parameters involved when a float having both horizontal and vertical velocity contacts a water surface are presented. The data were obtained at the Langley impact basin, which is described in detail. The report is confined to a presentation of the relationship between resultant velocity and impact normal acceleration for various float weights when all other parameters are constant. Analysis of the experimental results indicated that the impact normal acceleration was proportional to the square of the resultant velocity, that increases in float weight resulted in decreases in impact normal acceleration, and that an increase in the flight-path angle caused increased impact normal acceleration.

229. Abel, G. C.: Rough Water Tests on a Sunderland Flying Boat. Rep. No. F/Res/133, British M.A.E.E., Sept. 4, 1939.

Rough-water tests were conducted on a Sunderland flying boat to determine the feasibility of its operation from Malta. Preliminary tests were made at Felixstowe in a 3- to 5-foot swell and further tests were made at Malta where water pressures and accelerations were measured at loads from 46,000 to 51,000 pounds in different sea and wind conditions (swells as high as 6 ft).

The flying boat took off and landed successfully in Marsa Scirocco Bay at Malta under practically all the conditions experienced. The

HYDRODYNAMICS
Unsteady Longitudinal Forces and Moments - Lift

highest acceleration was 3.8g obtained in a landing during the preliminary tests at Felixstowe in which the planing bottom was slightly damaged. The highest water pressure measured was 14.8 pounds per square inch on a landing, the acceleration for which was 2g. After a number of take-offs at Marsa Scirocco Bay both wing-tip floats were found to be damaged; an acceleration of 2g had been recorded five times before the failure.

Difficulty was experienced during take-off in maintaining a straight course into the waves. Piloting technique in the various seaways was discussed and it was noted that excellent piloting may have considerably affected the measured results.

230. Batterson, Sidney A.: Variation of Hydrodynamic Impact Loads with Flight-Path Angle for a Prismatic Float at 3° Trim and with a $22\frac{1}{2}°$ Angle of Dead Rise. NACA RB No. L5A24, 1945.

Tests were made in the Langley impact basin to determine the relationship between impact normal acceleration and flight-path angle $\gamma$ for seaplanes landing on smooth water. The tests were made at both high and low forward speeds with the model at 3° trim. The model had a dead-rise angle of $22\frac{1}{2}°$ and, with the drop linkage, weighed 1100 pounds. The results of the tests indicated that the maximum impact normal acceleration was proportional to $\gamma^{1.36}$ over the test range of flight-path angle and that the effects of gravity forces appeared during the immersion process after normal acceleration had occurred.

231. Batterson, Sidney A., and Stewart, Thelma: Variation of Hydrodynamic Impact Loads with Flight-Path Angle for a Prismatic Float at 6° and 9° Trim and a $22\frac{1}{2}°$ Angle of Dead Rise. NACA RB No. L5K21, 1946.

Tests were made in the Langley impact basin to determine the relationship between impact normal acceleration and flight-path angle $\gamma$ for seaplanes landing on smooth water. The tests were made at both high and low forward speeds and at trims of 6° and 9°. The model had a dead-rise angle of $22\frac{1}{2}^{\circ}$ and a gross weight of 1100 pounds. (1040 lb from data). The results of the tests indicated that the maximum impact normal acceleration was proportional to $\gamma^{1.54}$ for $6^{\circ}$ trim and $\gamma^{1.33}$ for $9^{\circ}$ trim over the test range of flight-path angle. It was further observed that at low flight-path angles there was a predominance of the dynamic forces arising from the downward deflection induced in the water impinging on the float bottom; whereas at high flight-path angles the forces resulting from the virtual mass predominated. The maximum depth of immersion and the immersion which occurred at the instant of maximum normal force showed very little effect of trim.

232. Batterson, Sidney A.: Variation of Hydrodynamic Impact Loads with Flight-Path Angle for a Prismatic Float at $12^{\circ}$ Trim and with a $22\frac{1}{2}^{\circ}$ Angle of Dead Rise. NACA RB No. L5K21a, 1946.

Tests were made in the Langley impact basin to determine the relationship between impact normal acceleration and flight-path angle $\gamma$ for seaplanes landing on smooth water. The tests were made with varying resultant velocities with the model at $12^{\circ}$ trim. The model had a dead-rise angle of $22\frac{1}{2}^{\circ}$ and its total weight was 1100 pounds. The results of the tests indicated that the maximum impact normal acceleration was proportional to $\gamma^{1.22}$ over the test range of flight-path angle and that the maximum normal impact acceleration occurred prior to or at the instant of chine immersion.

(See also abstract 96.)

Steady Lateral Forces and Moments

(See abstract 280.)

HYDRODYNAMICS
Steady Lateral Forces and Moments - Heeling Moment

233. The William Froude National Tank Staff and Grigg, A. D.: Experiments with Models of Seaplane Floats. Ninth Series. R. & M. No. 188, British A.C.A., 1919.

The majority of single-float seaplanes are unstable in heel and are stabilized by the wing-tip floats and the dynamic action of the water flowing along the bottom of the main float. A measure of the transverse instability of three models of flying-boat hulls (without wing-tip floats) was obtained at the William Froude National Tank by ascertaining the vertical force required at the position of the wing-tip float to keep the wing tip just out of water at various speeds. It was found that this force decreased with increasing speed and became zero at hump speed. The same general result was found for all three models, which differed only in the transverse shape of the bottom. The transverse stability of a flying boat under way and considerations in the design of wing-tip floats are discussed.

(See also abstracts 204 and 332.)

Steady Lateral Forces and Moments - Yawing Moment

234. Locke, F. W. S., Jr.: Some Yawing Tests of a 1/30-Scale Model of the Hull of the XPB2M-1 Flying Boat. NACA ARR No. 3G06, 1943.

The results obtained from yawing tests of a $\frac{1}{30}$-scale model of the complete hull of the XPB2M-1 (Stevens model 404) are shown to be in substantial agreement with preliminary full-scale flight tests on the flying boat. The model tests cover the entire range of speeds up to get-away, on the basis of the designed gross weight of the flying boat (140,000 lb).

Reports of preliminary flight tests of the XPB2M-1 flying boat indicated that there was a definite tendency toward directional instability in the vicinity of the hump. The model tests show that the hull is unstable at speeds up to and just past the hump. It was found that, within the range of speed coefficient $C_V$ from 2.0 to 2.5, the curves of yawing moment are discontinuous at small yaw angles and this result has been associated with the difficulty found in the preliminary flight tests.

(See also abstract 279.)

## Forces and Moments - Pressure Distributions

235. Locke, F. W. S., Jr.: Investigation of Bottom Pressures and of the Effect of Step Ventilation on a Seaplane Hull. Rep. No. 173, Stevens Inst. Tech., Dec. 14, 1941.

Tests were made to determine the pressure distribution over the bottom of a seaplane hull and the effect of step ventilation on the pressure distribution, resistance, trim, and rise at load coefficients of 0.456, 0.913, and 1.826. A few tests were made with the step (depth, 7 percent beam) ventilated to determine the directions and approximate magnitudes of the local flow velocities at various points on the bottom. A mixture of lampblack and linseed oil, which would streak out from a spot source, was used. Resistance tests of the forebody alone were made with the object of defining the maximum gain possible by step ventilation.

The observed pressure (referred to the undisturbed water level) on the forebody bottom started from a positive peak and then gradually decreased until at the step the pressure was negative. On the afterbody the pressure was first negative, then positive, and then decreased to negative at the stern. Ventilating the main step caused only small changes in the pressure distribution.

Ventilating the main step resulted in a slight reduction of resistance in the hump region at the light and medium values of load coefficient but had no appreciable effect at the heavy load coefficient. By testing the forebody alone, at the same attitudes as the complete hull, it was found that the resistance was reduced slightly less than 20 percent in the region of the hump. This gain is presumably the maximum that might be effected by step ventilation. Actually, ventilation reduced the total resistance about 5 percent.

HYDRODYNAMICS
Forces and Moments - Pressure Distributions

236. Jones, E. T., and Davies, W. H.: Measurement of Water Pressure on the Hull of a Boat Seaplane. R. & M. No. 1638, British A.R.C., 1935.

Introductory.- The object of the tests was to provide data for the designers of boat seaplanes.

Range of investigation.- The pressure over the hull bottom of a Southampton boat seaplane has been recorded at 23 stations during a series of normal landings and take-offs at different weights and during abnormal landings at one weight. The pressure has also been recorded during take-off and landing in a $3\frac{1}{2}$-foot sea.

During two of the abnormal landings where the rate of descent at impact was high the pressure distribution and the normal force on the hull has been deduced.

Conclusions.- The intensity of pressure during a normal landing made in calm water is higher than during the take-off. The area over which the pressure extends is from the front step to a point along the keel about a beam length forward of the front step. The mean pressure intensity over this area irrespective of time is about 7 pounds per square inch at the normal load (15,300 lb) and varies approximately as $W^{1.7}$ (where W is weight), while the mean simultaneous pressure is only about 4 pounds per square inch.

Local pressures of approximately 30 pounds per square inch were recorded twice, once close to the keel and about 3 feet forward of the front step during a stalled landing with sideslip and with a rate of descent of 9.5 feet per second and once close to the front step during a stalled landing at very high attitude.

Very high pressures are not registered over a large area simultaneously. The largest area over which a pressure greater than 25 pounds per square inch was registered was about 11 square feet, but the corresponding simultaneous pressure over this area was only 14 pounds per square inch. In general, the simultaneous pressure distribution is only about half the peak distribution.

The pressure aft of the front step is negligible in normal landings and the highest pressure reached in an abnormal landing was 7 pounds per square inch at the rear step.

HYDRODYNAMICS
Forces and Moments - Pressure Distributions

High pressures are distributed over a larger area during normal landings and take-offs in a rough sea than during abnormal landings made in a calm sea, and it is possible that normal tests made in 4-foot sea accompanied by a swell would give pressures exceeding those during abnormal tests made in a calm sea. From 5 feet forward of the main step to the main step the hull skin has progressively distorted during the tests and some fractures have occurred. Since the hull was in good condition and had made 400 landings in the course of three years' normal service use prior to these tests, it would appear that the hull design is adequately stiff to meet service requirements, though it should be mentioned that no heavy seas had been encountered during this period.

237. Thompson, F. L.: Water Pressure Distribution on a Flying Boat Hull. NACA Rep. No. 346, 1930.

The results of the last of a series of three investigations by the National Advisory Committee for Aeronautics of the water pressures on seaplane floats and hulls are presented. The tests consisted of determining the water pressures and accelerations on a Curtiss H-16 flying boat during landing and taxying maneuvers in smooth and rough water.

The results show that the greatest water pressures occur near the keel at the main step, where the maximum pressure is approximately 15 pounds per square inch. From this point, maximum pressures decrease in magnitude toward the bow and the chine. Pressures of approximately 11 pounds per square inch were experienced at the keel slightly forward of the middle of the forebody when taking off in rough water. The area of the forebody subjected to considerable pressure is roughly a triangle having its base at the step and its apex on the keel at the forward load water line. On the afterbody bottom, a maximum pressure of 8 pounds per square inch is nearly uniform. A vertical acceleration of 4.7g is the greatest value encountered in landings and is considerably greater than any other value recorded. It was found that 3g is approximately the maximum to be expected in take-offs in rough water and that this value was exceeded during only a few landings. A longitudinal acceleration of 0.9g was attained once in a landing in rough water, and 0.7g is not unusual for take-offs in rough water. The maximum lateral acceleration attained in cross-wind landings is approximately 0.5g. The results show that the landing loads were usually borne by an area near the main step and that rough water may cause large loads to be applied near the middle of the forebody.

238. Thompson, F. L.: Water-Pressure Distribution on a Seaplane Float. NACA Rep. No. 290, 1928.

The investigation reported herein was conducted to determine the distribution and magnitude of water pressures likely to be experienced on seaplane hulls in service. It consisted of the development and construction of apparatus for recording water pressures lasting one one-hundredth second or longer and of flight tests to determine the water pressures on a Vought UO-1 seaplane float under various conditions of taxying, take-off, and landing.

The apparatus developed was found to operate with satisfactory accuracy and is suitable for flight tests on other seaplanes.

The tests on the UO-1 seaplane showed that maximum pressures of about 6.5 pounds per square inch occurred at the step for the full width of the float bottom. Proceeding forward from the step the maximum pressures decreased in magnitude uniformally toward the bow, and the region of highest pressures narrowed toward the keel. Immediately abaft the step the maximum pressures were very small but increased in magnitude toward the stern, where a value of about 5 pounds per square inch was reached once.

239. Thompson, F. L.: Water Pressure Distribution on a Twin-Float Seaplane. NACA Rep. No. 328, 1929.

The results of the second of a series of investigations to determine water-pressure distribution on various types of seaplane float and hull are presented. Measurements were made of the water pressures and accelerations on a TS-1 twin-float seaplane during numerous landing and taxying maneuvers at various speeds and angles.

The results of this investigation show that water pressures as great as 10 pounds per square inch may occur at the step in various maneuvers and that pressures of approximately the same magnitude occur at the stern and near the bow in hard pancake landings with the stern well down. At other parts of the float the pressures are less and are usually zero or slightly negative for some distance abaft the step. A maximum negative pressure of 0.87 pound per square inch was measured immediately abaft the step. The maximum positive pressures have a duration of approximately one-twentieth to one-hundredth second at any given location and are distributed over a very limited area at any particular instant. The greatest accelerations measured normal to the thrust line at the center of gravity occurred in pancake landings, and a maximum of 4.3g was recorded. Approximate load-distribution curves for the worst landing conditions are derived from the data obtained to serve as a guide in static tests.

(See also abstracts 16, 82, 83, 171, 134, 227, 327, and 401.)

## Spray and Wake

240. Locke, F. W. S., Jr.: An Analysis of the Main Spray Characteristics of Some Full-Size Multiengine Flying Boats. NACA TN No. 1091, 1946.

An analysis is made of available full-scale and model data on the height of the main spray at the propeller plane of modern multiengine flying boats. The results are presented in both tabular and graphical form.

Scale effect on the height of the spray was observed and is indicated graphically. Differences in the height of the spray are attributed to scale effect in the Weber number and to the effect of slipstream, as the models were tested without power.

It was found that, with fixed load coefficient and forebody length-beam ratio, increasing the beam will increase the spray height at a slightly greater rate than would be expected according to the Froude law. By an adjustment of the data to a common beam, a correlation of spray height and forebody length-beam ratio indicated that an increase in forebody length-beam ratio appreciably reduced the height of spray.

HYDRODYNAMICS
Spray and Wake

The results should be useful in preliminary design for determining the height of hull necessary to keep the propellers clear of the main spray. These design curves are specifically for multiengine flying boats of generally conventional design.

241. Parkinson, John B.: Design Criterions for the Dimensions of the Forebody of a Long-Range Flying Boat. NACA ARR No. 3K08, 1943.

A correlation is made of the gross-load coefficient and the forebody length-beam ratio for a limited number of present-day multiengine long-range flying boats for which the spray characteristics are known. The spray criterion and the derived relationships permit a choice of dimensions of the forebody for various degrees of seaworthiness and permit the evaluation of the relative effect of forebody length, beam, and length-beam ratio for a proposed design.

It is concluded that the gross-load coefficient for comparable spray characteristics varies as the square of the forebody length-beam ratio. The forebody length has a relatively greater influence than the beam on the low-speed spray characteristics. When the length and the beam are both varied to maintain comparable sizes of forebody, the effect of length is not so pronounced as when length alone is varied. Large increases in length-beam ratio are required for comparable sizes of hull to obtain a definite improvement in the spray characteristics. Comparable spray characteristics may be obtained with a smaller forebody by use of high length-beam ratios.

The spray characteristics of the various flying boats are satisfactorily related by the equation

$$C_{\Delta_0} = k\left(\frac{L_f}{b}\right)^2$$

where

$C_{\Delta_0}$ gross-load coefficient $\left(\Delta_0/wb^3\right)$

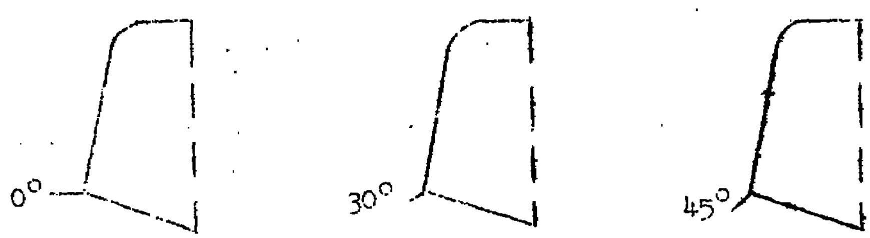
$L_f/b$ forebody length-beam ratio

k a constant that apparently varies approximately linearly with the the severity of the spray characteristics and has the following values:

0.0525 for very light spray
.0675 for satisfactory spray
.0825 for heavy spray
.0975 for excessive spray

242. Truscott, Starr: The Effect of Spray Strips on the Take-Off Performance of a Model of a Flying-Boat Hull. NACA Rep. No. 503, 1934.

The effect on the take-off performance of a model of the hull of a typical flying boat - the Navy PH-1 - of fitting spray strips of four different widths, each at three different angles, was determined by resistance-model tests in Langley tank no. 1. Spray strips of widths up to 3 percent of the beam improve the general performance at speeds near the hump and reduce the spray thrown. A downward angle of 30° to 45° in the neighborhood of the step seems most favorable for the reduction of the spray. The spray strips have a large effect in reducing the trimming moments at speeds near the hump speed but have little effect on them at high speeds.




243. King, Douglas A., and Mas, Newton A.: Effects on Low-Speed Spray Characteristics of Various Modifications to a Powered Model of the Boeing XPBB-1 Flying Boat. NACA ACR No. L5F07, 1945.

A $\frac{1}{10}$-size powered dynamic model of the Boeing XPBB-1 flying boat was tested in Langley tank no. 1 to observe the effects of trim and powered propellers, of lengths of forebody and afterbody, and of various spray strips upon the low-speed spray characteristics.

The effects of powering the propellers were to decrease the trim and to pick up spray that would not hit the propeller disks when the propellers were windmilling. Decreasing the trim raised the height of the spray with respect to the hull.

Changes in the length of forebody or afterbody that increased the ratio of forebody length to afterbody length increased the trim and reduced the intensity of spray in the propellers.

Spray strips having the form of thin plates projecting vertically downward from the forebody chines were found to be very effective in preventing spray from striking the propellers. Fillets between the spray strips and the bottom of the hull markedly reduced the effectiveness of the spray strips. The unfilleted vertical spray strips were about as effective in controlling the spray as spray strips of the same length having a downward angle of 30° and extending out from the chine to increase the beam by almost 13 percent.

244. Bottomley, G. H.: Experiments with Models of Seaplane Floats. Eleventh Series. Part III. The Wave Formations Produced by a Seaplane of the Single Float Type. R. & M. No. 365, British A.C.A., 1919.

Tests were made of a seaplane float at the William Froude National Tank to investigate the contours of the waves behind the forebody alone and behind the forebody and afterbody in combination. Transverse sections of the waves at several distances behind the model were obtained by means of graduated pointers moved up and down so as to touch the water surface.

The effects of trim, speed, and draft were observed for the forebody of a typical model. Forebodies having a flat bottom, a rounded bottom, and a rounded bottom with chine flare were tested at only one trim and draft but several speeds.

HYDRODYNAMICS
Spray and Wake

Similar tests were made in conjunction with various afterbodies in which the shape of the bottom, the beam of the second step, and the longitudinal position of the second step were varied.

245. Locke, F. W. S., Jr.: "General" Main-Spray Tests of Flying-Boat Models in the Displacement Range. NACA ARR No. 5A02, 1945.

A method is presented for showing, by means of three curves, the locations of the points of tangency to the envelope of the main-spray blisters generated by flying-boat-hull models, as obtained from "general" tests in the speed range up through the hump (displacement-speed range). For a given model there is one curve each for the longitudinal position, the lateral position, and the vertical position of the point of tangency of the main-spray blister with the crest of the envelope; each curve represents all the data taken at all combinations of load and speed in free-to-trim tests with a given position of the center of gravity. The relationships used are

$$C_X/C_\Delta^{1/3} = \phi_1\left(C_V^2/C_\Delta^{1/3}\right) \qquad \text{for longitudinal position}$$

$$C_Y/C_\Delta^{1/3} = \phi_2\left(C_V^2/C_\Delta^{1/3}\right) \qquad \text{for lateral position}$$

$$C_Z/C_\Delta = \phi_3\left(C_V^2/C_\Delta^{1/3}\right) \qquad \text{for vertical position}$$

in which $C_X$, $C_Y$, and $C_Z$ are position coefficients based on beam, $C_\Delta$ is the load coefficient, and $C_V$ is the speed coefficient. These three relationships are tested by applying them to the data for seven different models and are found to be reasonably satisfactory for all the models. This method should be useful for extrapolating the limited data ordinarily obtained from specific tests, for reducing the number of tests required to obtain adequate indications from general tests, and for comparing hull forms of the same general type. It is intended to supplement, rather than to supplant, the method involving two-view drawings of the spray previously developed.

[redacted]

HYDRODYNAMICS
Spray and Wake

246. Olson, Roland E.: Investigation of the Effect of Spray Strips on the Low-Speed Spray Characteristics of a 1/8-Size Model of the Consolidated PB2Y-3 Flying Boat - NACA Model 116E-3. NACA MR, Bur. Aero., Jan. 27, 1943.

Because of the excessive spray in the propellers of the Consolidated PB2Y-3 flying boat at loads heavier than the original design gross weight (56,000 lb), various spray strips were installed on a powered dynamic model and investigated to determine the most practicable arrangement.

It was found that results from investigations of the spray characteristics with models are subject to an appreciable error if the effects of slipstream on the spray pattern are not included. Spray strips were developed which successfully eliminated the spray in the propellers at loads up to 72,500 pounds.

247. Truscott, Starr, and Daniels, Charles J.: Investigation of the Effect of Ventilation on the Flow of Water over a Rounded Chine. NACA RB, Feb. 1943.

In aerodynamic tests a flow of air across the sharp chines of a conventional flying-boat hull, which was probably responsible for considerable air drag, was noticed. An investigation was made to determine the possibility of replacing the conventional sharp chine of a hull by a rounded surface in which the desired separation of the water at the chine during take-off and landing is induced or aided by ventilation of the chine. (See fig. 1.)

It was seen that the air flowing from the slot caused the water to break free of the curve of the bottom and that the height to which the spray was thrown was determined by the position of the slot; a low position caused the spray to fly low and a high position caused it to rise high. The action of the slot was improved by introducing the air approximately tangentially. (See fig. 2.) This configuration

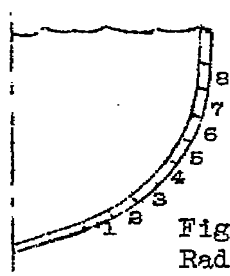


Figure 1.- Radial slots.

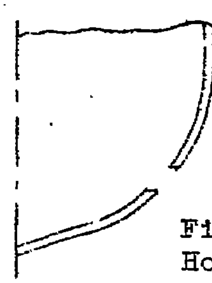


Figure 2.- Horizontal slot.

prevented the rising water as it crossed the slot from encountering a surface that would deflect it toward the interior of the hull. None of the arrangements tested gave spray patterns so desirable as those from a planing surface with conventional sharp chines under parallel conditions.

248. Olson, Roland E., and Daniels, Charles J.: Investigation of the Low-Speed Spray Characteristics of the Navy PBN-1 Airplane - NACA Model 124E. NACA MR, Bur. Aero., March 19, 1943.

The spray from the bow of the original Navy PBN-1 flying boat at taxying speeds was thrown up over the forward deck, wetting the forward gun turret and the pilot's windshield. This undesirable spray was reduced by the addition of spray strips on the chines at the bow. The manner in which the spray could be controlled by the fitting of spray strips was investigated in Langley tank no. 1 on a $\frac{1}{8}$-size powered dynamic model.

The low-speed spray characteristics of the basic model with the Naval Aircraft Factory chine strips (slightly increased length and breadth of the bow and a 30° down flare at the chine) appeared to be satisfactory for simulated loads up to 35,000 pounds in both smooth and rough water. With this modification, increases in gross weight appeared to be limited by possible spray damage to the propellers rather than by spray over the bow.

249. Locke, F. W. S., Jr., and Bott, Helen L.: A Method for Making Quantitative Studies of the Main Spray Characteristics of Flying-Boat Hull Models. NACA ARR No. 3K11, 1943.

A method and apparatus for making quantitative tests of the spray characteristics of flying-boat-hull models have been developed. Three-view photographs are taken on one negative with the aid of mirrors, measurements are made from the photographs, and the results are presented in the form of charts that show the side view and the front view of the envelope curves of the principal features of the spray as functions of speed and load. The spray envelopes are located on these charts with reference to the model so that, by superimposing a transparent drawing of a proposed complete flying boat, interference of spray with parts of the flying boat may be detected at a glance.

The method is applied to three related models of flying-boat hulls that differ in dead rise. Spray and roach characteristics in smooth water are considered. The models had no tail extensions and were not self-propelled.

From the results obtained, it is concluded that angles of dead rise larger than are ordinarily employed produce slightly lower spray blisters in the low-speed range and that smaller angles of dead rise are quite undesirable, especially at high speeds. It is concluded, also, that the roach at the stern, which may interfere with the tail cone at speeds just prior to the hump, becomes lower as the angle of dead rise is increased.

In the appendix, a review is made of the problem of scale effect in spray measurements on models. Apart from questions regarding the effect of propeller slipstream, model and flying boat may be expected to have strikingly similar spray under corresponding conditions.

250. Stout, E. G.: Model 31 - Hydrodynamic Characteristics. Rep. No. ZH-31-012, Consolidated Aircraft Corp., March 1941.

A summary of the development of the Consolidated model 31 flying boat is presented.

The original hull was patterned after a successful DVL hull but had extensive modifications to improve the structure and to simplify manufacture. After construction was under way, the step was moved forward on the basis of tests of a dynamic model.

Flight tests of the flying boat showed that the spray was very heavy. The stable range of center-of-gravity position was extremely small (about 2 percent M.A.C.); there was a strong tendency for the airplane to jump into the air on take-off before the pilot was ready to leave the water; and landings were unstable.

HYDRODYNAMICS
Spray and Wake

The wing-tip floats gave extensive trouble until they were redesigned on the basis of dynamic-model tests made by the Consolidated Aircraft Corporation.

Tank tests of a dynamic model were made by the NACA to investigate modifications that might improve the spray characteristics. As a result of these and other tests, the flying boat was modified by making the forebody lines less bluff, by dropping the forebody hull to make the step deeper, by changing from a straight step to a 30° V-step, and by moving the step forward. These changes resulted in improvement in all hydrodynamic characteristics except landing stability. The best landings were made by either a full-stall approach or a fast low-trim approach with flaps retracted rapidly upon contact with the water.

Dynamic-model testing was developed in this country by the Consolidated Aircraft Corporation at about the same time model 31 was designed. The basic design of model 31 was complete and construction had been started before any hydrodynamic tests were made. Had the reliable tests possible today been available for study during the early design stages, many basic errors could have been avoided.

251. Pierson, J.: Model XPB2M-1 - Towing Basin Spray Studies at the Wing Flaps. Appendix A by C. E. Kahlke, Jr. Rep. No. 1678, The Glenn L. Martin Co., Aug. 25, 1942.

Brief tests were made at the Stevens tank on a $\frac{1}{30}$-size model of the Martin XPB2M-1 flying boat fitted with tubes and wires representing the leading and trailing edges of the flaps, respectively, to investigate the extent and height of the spray in the vicinity of the flaps. Increasing the gross load raised the height of the spray. A heel of 5° caused the spray on the down side to rise higher and to be closer to the side of the hull.

Appendix A gives the results of tests made to investigate the effects of various modifications to the forebody chine on the spray near the flaps in the heeled condition. Adding spray strips which extended beyond the sides of the hull or increasing the chine flare adequately prevented spray from hitting the flaps. Some results of tests of three forebodies without afterbodies are shown.

HYDRODYNAMICS
Spray and Wake

252. Anon.: Note on Some Tank Tests on a Modified Bow Form for the Short Sunderland. Rep. No. B.A. 1618, British R.A.E., June 1940.

Tank tests were made to determine the reduction in spray through the propellers during take-off at heavy overloads due to modification of the hull lines near the bow. The modification consisted in moving the chines near the bow outward and downward and giving the sections more down flare near the chines.

Specific resistance tests were made for two gross loads and five trims at speeds from rest to get-away. Dynamic model tests were made to determine the spray and porpoising characteristics in smooth water and in 3-foot waves (full size) of varying wave length. The results obtained from the modified form were compared with the results of standard hull forms under the same conditions.

The spray in the propellers was most severe between 15 and 20 knots and was heaviest in the inboard propellers, which is in agreement with full-scale results. The modified form gave a very slight improvement in the range of speed over which the propellers were wetted in a short wave. The intensity of wetting, however, was about the same in both cases. The modified and standard forms had similar porpoising characteristics. The resistance of the modified form was slightly lower at the lower speeds and attitudes.

253. Locke, F. W. S., Jr.: Some Systematic Model Experiments of the Bow-Spray Characteristics of Flying-Boat Hulls Operating at Low Speeds in Waves. NACA ARR No. 3L04, 1943.

Tests were run in the Experimental Towing Tank at the Stevens Institute of Technology on models of three flying boats, the XPB2M-1, the XPBB-1, and the JRM-1 and on 11 other models derived from the XPB2M-1 to determine the effect of bow form on the amount of spray thrown onto the windshield of a flying boat in rough water at low taxying speeds. The variables studied include the effect of length-beam ratio, the effect of hull dead rise, the effect of forebody warping, the effect of changes of the bow alone, and the effect of angle of afterbody keel.

The results obtained from tests of these models indicated that the height and the volume of spray at the windshield can be reduced

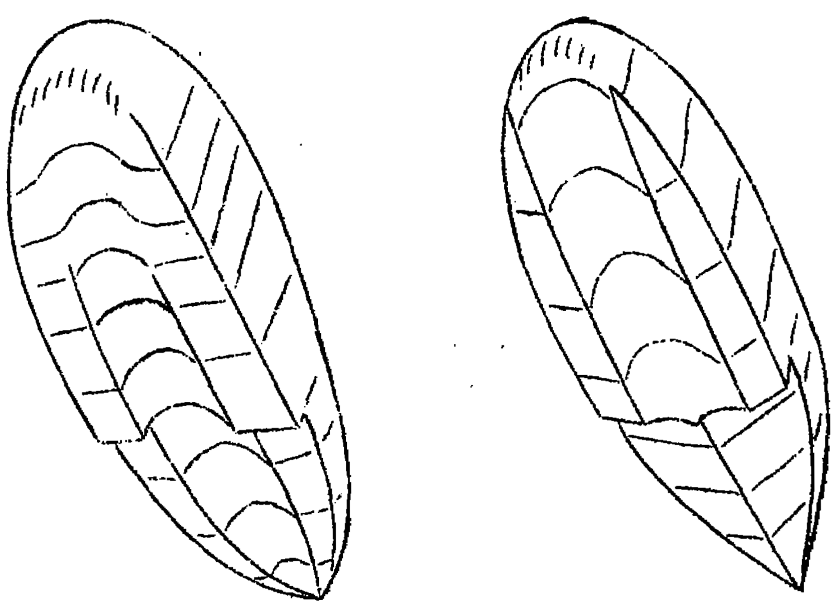
HYDRODYNAMICS
Spray and Wake

by (1) increasing the hull length and especially the forebody length, (2) increasing the "sharpness" of the bow lines below the chine (3) increasing the static trim when the bow form is such that relatively bad spray otherwise occurs, and (4) decreasing the water-borne load. These changes are listed approximately in the order of their importance from the point of view of reducing spray.

It was concluded that any change in hull form which softens the impact between hull and waves tends to reduce the spray thrown onto the windshield at low speeds.

254. Land, Norman S., and Woodward, David R.: Spray and Stability Characteristics of a Dynamic Model of the PB2Y-3 Airplane with Transversely Arched Bottoms - NACA Models 165B and 165C. NACA MR, Bur. Aero., March 27, 1944.

Several attempts have been made to reduce the excessive bow spray encountered on some flying boats. Some of these attempts have been to completely redesign the hull to an unconventional form. One form that offers almost complete freedom from external bow spray is the tunnel- or arched-bottom hull. This report describes preliminary stability and spray tests made in Langley tank no. 1 of a powered dynamic model with various configurations of arched bottoms.



HYDRODYNAMICS
Spray and Wake

The limited experience gained with the arched-bottom hulls that were tested leads to the conclusion that if satisfactory stability characteristics are to be obtained the design of the afterbody and step must be such as to provide a large afterbody clearance.

255. Land, Norman S., and Woodward, David R.: Tank Tests of a 1/8-Full-Size Dynamic Model of the Consolidated Vultee PB2Y-3 Airplane with a Lengthened Forebody and Afterbody and Various Modifications of the Step. NACA MR, Bur. Aero., March 4, 1944.

Tests were made for the purpose of determining the effect of a lengthened bow and afterbody on the spray and longitudinal hydrodynamic stability. A 27-percent increase in the length of the bow and a 20-percent increase in the length of the afterbody (increase in length-beam ratio from 5.18 to 6.41) practically eliminated the spray passing through the propellers at a gross load corresponding to 76,000 pounds full size. At a gross load of 96,000 pounds full size, the bow spray of the model with the lengthened bow appeared less severe than that of the basic model at a gross load of 76,000 pounds.

Increasing the depth of step greatly improved the take-off and landing instability. Comparable stability between transverse and 30° V-steps could be obtained on this model only by making the transverse step as deep as the 30° V-step at its keel.

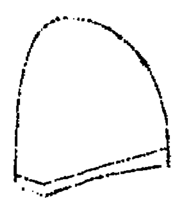
256. Parkinson, John B., and Dawson, John R.: Tank Tests of a Model of the Hull of the Boeing 314 Flying Boat to Investigate the Wave Formation at Low Speeds (N.A.C.A. Model 72-P). NACA MR, Boeing Aircraft Co., Jan. 19, 1940.

Tank tests were made of a $\frac{1}{10}$-size model of the hull of the Boeing 314 flying boat to obtain data on the wave form around the hull in the vicinity of the stub-wing stabilizers. The profiles of the wave form were obtained by using a parallel-motion device, which was arranged to trace the intersection of the water surface and a series of vertical planes parallel to the plane of symmetry of the model. The data were taken with the model free to trim at three different conditions of heel and yaw. A number of photographs, including a set of stereoscopic photographs, are given to illustrate the flow around the model.

HYDRODYNAMICS
Spray and Wake

257. Billett, H.: Tank Tests on Special Clean-Running Floats for a Twin Float Seaplane. Rep. No. Aero 1719, British R.A.E., Dec. 1941.

Tests were made to develop clean-running floats that would be suitable for an existing type of twin-float seaplane. Spray between the standard floats resulting from the meeting of the two bow blisters entered the propellers in excessive amounts. A pair of floats was designed having the whole of the planing bottoms arranged on the outer sides of the floats. (See fig.) These floats were found to be clean-running and to have porpoising, water-resistance, and directional-stability characteristics as good as those of good conventional floats but probably higher air drag. Attempts to reduce the air drag introduced directional instability.



General cross-sectional
form of hull at step

258. Land, Norman S., and Woodward, David R.: Tests of a 1/8-Full-Size Dynamic Model of the XP4Y-1 Airplane with Spray Strips - NACA Model 143E. NACA MR, Bur. Aero., Nov. 20, 1943.

Tests were made of a powered dynamic model of the XP4Y-1 airplane equipped with spray strips in an attempt to improve the spray characteristics of the original model. The tests of the modified model were extended to determine the effect of acceleration during take-off on the limits of stable locations of the center of gravity, the effects of ventilation on landing stability, and the effect of reducing the span of the flaps from full span to approximately half span.

It was found that the spray strips very effectively deflected the spray downward so that only a few scattered drops entered the propeller disks. Changing the acceleration of the model from 1 foot per second per second to 3 feet per second per second changed each limit of stable locations of the center of gravity less than 2 percent of the mean aerodynamic chord, which was small compared with the effect of elevator or flap deflection. The tests indicated that the "jump" take-off and skipping at landing which had been reported after flight tests were probably due to insufficient step ventilation.

258a. Brooke, H. E.: Summary of Dynamic Tank Tests of the 1/8-Scale XP4Y-1 with Spray Strips. Rep. No. ZH-31-018, Consolidated Vultee Aircraft Corp., Aug. 1943.

This report gives a summary of the results of the tests reported in abstract 258.

259. MacPhail, D. C., and Tye, W. D.: The Waves Close behind a Planing Hull. Rep. No. Aero 1992, British R.A.E., Nov. 1944.

A number of cases have arisen in which large amplitude high-speed porpoising of flying-boat models seemed to be seriously aggravated by inopportune striking of the rear step on the surface of the trough behind the main step. In order to predict such an occurrence, the shape of the trough should be known.

A review of a number of the existing solutions for the transverse waves behind a planing surface is given, and the importance of diverging waves over transverse waves at planing speeds is pointed out. An approximate solution is evolved and is compared with experimental measurements.

The divergent wave system behind a planing hull can account for the main features of the experimental trough observations; however, a number of systematic discrepancies occur that are attributed mainly to the pressure field around the hull and to the transverse wave formation. Empirical corrections are introduced to compensate for this defect, and the resulting formulas are collected for practical use.

260. Maller, Monroe A.: XP4Y-1 - Hydrodynamic Characteristics as Determined from Flight Tests. Part I - With Spray Strips. Rep. No. ZH-31-019, Consolidated Vultee Aircraft Corp., Sept. 1943.

A summary is made of flight tests of the Consolidated Vultee XP4Y-1 flying boat with particular attention given to the hydrodynamic characteristics with spray strips installed. Data at gross weights of 46,000, 51,000, and 54,000 pounds were obtained by visual observation and by automatic recording with the NACA events recorder.

HYDRODYNAMICS
Spray and Wake

Because of the length of time involved in working up the events-recorder records, the results of only visual data are given.

At all gross weights tested, the spray through the propellers was light and passed through the lower third of the propeller disks. The spray over the tail surfaces, although of short duration, was very heavy at a gross weight of 54,000 pounds. The blunt nose of the spray strips did not contribute to control of spray and was removed. This change increased the top speed of the flying boat by about 3 or 4 miles per hour. The hydrodynamic center-of-gravity limits of stability were satisfactory, lying outside the aerodynamic center-of-gravity limits. The original amount of step ventilation was inadequate to prevent "jump" take-offs and skipping. Almost doubling the amount of ventilation, on the basis of dynamic model tests conducted by the National Advisory Committee for Aeronautics, practically eliminated jump take-offs and skipping. Directional stability at normal gross weights was satisfactory and became marginal at 54,000-pounds gross weight.

(See also abstracts 83, 87, 110, 121, 123, 130, 133, 137, 142, 144, 145, 153, 168, 169, 173, 180, 184, 203, 268, 279, 280, 283, 290, 292, 300, 311, 314, 317, 321, 329, 330, 331, 333, and 399.)

Stability Under Way

(See abstracts 27 and 375.)

Longitudinal Stability Under Way

261. White, H. G., Smith, A. G., and Shaw, R. A.: Attitude and Stability Measurements on a Half Scale Sunderland Hull Fitted to the Scion Seaplane. Rep. No. H/Res/158, British M.A.E.E. Dec. 28, 1942.

This report is primarily on M.A.E.E. stability tests of a half-scale Sunderland hull on a Scion seaplane. It is of particular value as a source of information on the stage between small tank models and the full-scale flying boat and on scale effect.

The first object of the report, therefore, lies in a comparison of the half-scale results with (a) the full-scale Sunderland, and (b) the small-tank-model results. A direct comparison is also made of the two sets of tank results on the $\frac{1}{16}$ scale of the Scion and the $\frac{1}{15}$ scale of the Sunderland and of the model Sunderland with the full-scale Sunderland.

The measurements of stability on the Scion are in good agreement with the full-scale results but in poor agreement with the small model tests in the tank. The latter discrepancy may be due to the absence of slipstream in tank tests, a feature which is now being more fully corrected in the latest tests. The present method of disturbing the models seems to have increased the discrepancy between the model and the full-scale flying boat. Further modification of tank technique and a reexamination of full-scale stability limits appear necessary in order to find a closer correlation between model and full scale.

262. Ebert, John W., Jr.: A Comparison of the Porpoising Limits of Two Flying Boats and Their Tank Models. NACA RB, Feb. 1943.

A comparison was made of the porpoising limits of two flying boats and their tank models to determine the scale effect. The models were tested without leading-edge slats or powered propellers and although the lower limits were in good agreement the upper limits occurred at a higher speed which indicated an appreciable effect of scale on the lift coefficient. The model results may also have been influenced by the reduced airspeed beneath the towing carriage.

263. Locke, F. W. S., Jr.: General Porpoising Tests of Flying-Boat-Hull Models. NACA ARR No. 3I17, 1943.

This report gives evidence in support of the propriety of substituting, for many practical purposes, a "general" porpoising test of flying-boat-hull models in place of the usual "specific" test.

HYDRODYNAMICS
Longitudinal Stability Under Way

The results of a general test of a particular model are presented and compared with the results of a specific test of the same model.

The report also discusses appropriate average values of the variables necessarily considered for ordinary use in general testing. These variables are aerodynamic pitch-damping rate $M_q$, pitching moment of inertia, and position of center of gravity.

The terms "general" and "specific" are used in the sense in which they have been used for some time by the National Advisory Committee for Aeronautics in connection with resistance tests.

264. Klemin, Alexander, Pierson, John D., and Storer, Edmund M.: An Introduction to Seaplane Porpoising. Jour. Aero. Sci., vol. 6, no. 8, June 1939, pp. 311-318.

A summary of opinion and experience by several designers and operators is presented as a background in setting up a method of calculating hydrodynamic stability derivatives. The methods of Perring and Glauert are followed and Langley tank data are used to obtain dimensional values of hydrodynamic stability derivatives applicable to a typical example, a study of the Courtney Amphibian. The derivatives and the coefficients in the stability equation are tabulated and discussed to show the effects of location of the center of gravity and of the aerodynamic derivatives. The effects of arbitrary changes in derivatives and the character of the porpoising oscillations are discussed.

265. MacPhail, D. C., Tye, W. D., and Llewelyn-Davies, D. I. T. P.: Model Investigation on the Effect of Slipstream on the Longitudinal Stability of Flying Boats on the Water. Rep. No. Aero 1792, British R.A.E., Jan. 1943.

It has been suggested from time to time that the stability of flying boats during take-off may be affected by slipstream.

Porpoising tests, representing the take-off, in the normal condition, of a twin-engine flying boat, were carried out using two techniques: one allowed for the slipstream lift by means of a weight and pulley system, while in the other the slipstream was produced by means of propellers driven by compressed air turbines. The model was tested with two hull forms one of which was very stable while the other was unstable at high speeds; in both cases tests were made both with flaps up and with flaps 20° down.

The effect on the water stability of tailplanes of various sizes was investigated in the case of the unstable form. Tests were made with the normal tail plane, with the tail plane 60 percent oversize, and with the tail plane removed.

The unstable hull form was tested in waves at speeds in the neighborhood of the hump in order to observe the effect of the propellers on the spray.

The general effect of the slipstream is to widen the stable region. This effect was more noticeable for the unstable hull form than for the stable hull form.

Lowering the flaps during the take-off lessens the difference between the limits in the cases with and without propellers running, while the size of the tail plane has little effect on the water stability. The increase of stability with the propellers running can be attributed mainly to the disturbance of the air and water flow around the afterbody by the slipstream.

The alteration in the running angle by the slipstream confirmed earlier wind-tunnel work.

It was easier to assess the risk of damage by spray when the propellers were running than when they were idling or merely represented by stationary rings.

266. Davidson, Kenneth S. M., with Locke, F. W. S., Jr., and Suarez, Anthony: Porpoising - A Comparison of Theory with Experiment. NACA ARR No. 3G07, 1943.

A direct comparison is made between the observed and the calculated longitudinal dynamic stability of a particular dynamic model of a flying boat moving on the water. The calculations were made on the basis of the theory as stated by both Klemin and Glauert. Good agreement was obtained between experiment and theory (using the theory as stated by Glauert) for trims in the vicinity of the lower limit, at one speed a little above the hump.

The present form of the theoretical method is laborious. It depends for its application upon experimental constants that are not more easily determined than a direct experimental determination of stability, and it has not yet been shown to be capable of pointing out design trends tending to reduce instability to any greater extent than the direct experimental method.

267. Perring, W. G. A., and Glauert, H.: The Stability on the Water of a Seaplane in the Planing Condition. R. & M. No. 1493, British A.R.C., 1933.

The general stability equation has been written down and approximate expressions have been obtained for the stability derivatives. It has then been assumed that the porpoising was due to an interaction between the vertical and pitching motions, and the analysis has been applied to investigate in detail the stability of a seaplane traveling over the water and supported on either one or two steps. Finally, the influence of longitudinal freedom on the stability has been investigated.

The effect of longitudinal freedom is shown to have practically no effect on the stability, and hence porpoising may be regarded as an interaction of the vertical and pitching moments. Tests of a bare model without wings and tail plane are shown to be valueless and misleading, and a complete model should also have the correct ratio of mass to moment of inertia. In certain cases the influence of modifications to the seaplane has opposite effects, depending on whether one or two steps are in contact with the water. Wherever comparisons are possible, the results of the theoretical investigation agree with the recorded cases of porpoising observed during the tank testing of models and also with the full-scale experimental results for the Seagull. It is possible that some of the conclusions given in the report will be modified when experimentally determined derivatives are available to replace the rough values used in making the present calculations.

HYDRODYNAMICS
Longitudinal Stability Under Way

268. Parkinson, John B., and Olson, Roland E.: Tank Tests of a 1/5 Full-Size Dynamically Similar Model of the Army OA-9 Amphibian with Motor-Driven Propellers - NACA Model 117. NACA ARR, Dec. 1941.

The influence of running propellers on the hydrodynamic characteristics of a model of a seaplane was investigated in Langley tank no. 1 to evaluate the importance of power in tests of dynamically similar models. Various increments of power, including the power sufficient for self-propulsion, were applied; and a gear allowing fore-and-aft freedom of the model with respect to the towing carriage when self-propelled was provided.

It was found that, as in wind-tunnel work, the powered propellers have a large effect on the aerodynamic characteristics of the model and consequently on the hydrodynamic stability, which depends to a certain extent on those characteristics. The interference of the propellers and the slipstream with the wave system around the hull at taxying speeds is the most significant factor in the problems of spray control and limitation in load imposed by the spray. The use of powered models is therefore desirable in tank tests of new designs for a more precise prediction of stability and spray while taking off and landing.

In general, the magnitude of the effects of a given increment of power in such tests decreases as the power is increased. The use of powers and revolution speeds that are less than the scale values would be preferable to neglecting entirely the effects of the running propellers. Fore-and-aft freedom of the model has a negligible effect on the trims at which porpoising begins but changes the character of the motion somewhat.

(See also abstracts 169, 397, and 401.)

Longitudinal Stability Under Way - Low-Angle Stability

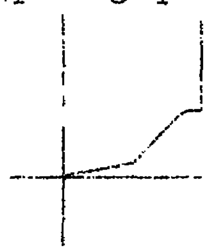
269. Benson, James M., and Lina, Lindsay J.: The Effect of Dead Rise upon the Low-Angle Type of Porpoising. NACA ARR, Oct. 1942.

Data pertaining to the forces and moments developed by V-bottom planing surfaces of different angles of dead rise were used to compute

HYDRODYNAMICS
Longitudinal Stability Under Way - Low-Angle Stability

the effect of the dead rise of the forebody upon the lower trim limit of stability of a seaplane. The results of the calculations were checked experimentally, with very good agreement, by use of a simplified model composed of a planing forebody and a tail plane having a controllable elevator. The results indicated in every case that an increase in dead rise within the range investigated (10° to 30°) caused an important increase in the lower trim limit of stability.

The present investigation also included tests of a model having a transverse section incorporating chine flare and an abrupt increase in dead rise at a point one-third of the beam outboard of the keel. This complex section proved to have very interesting stability characteristics at planing speeds near the hump where the lower trim limit was not greatly affected by load. These characteristics are in marked contrast to those of a simple V-bottom and indicate that departures from the simple shape of transverse section may produce results that cannot be safely predicted by assuming an equivalent V-bottom.



270. Wolfe, C. M.: Longitudinal Stability of the Seaplane Model XPBB-1 in the Planing Condition. Rep. No. D-4020, Boeing Aircraft Co., May 16, 1942.

This report deals with an analysis of data taken in dynamic model tests in the Langley tank of the $\frac{1}{10}$-size model XPBB-1 with reference to low-angle porpoising characteristics.

The correlation of these data indicates that the V-bottom as commonly employed on seaplane hulls gives rise to a discontinuity in the curves, coefficient of lift against coefficient of draft, and that it is just at this discontinuity that low-angle porpoising ceases with increasing speed or angle of trim. The discontinuity in lift is obviously due to the change from an approximately rectangular planing area to one of triangular shape as the water line on the chine edge reaches the main step. Motion pictures of tank tests and a mathematical analysis lend evidence to the conclusion that the tendency to porpoise at low angles in the case of the dynamic seaplane model XPBB-1 is largely eliminated when the wetted area becomes triangular in outline.

271. Benson, James M., and Freihofner, Anton: Methods and Charts for Computing Stability Derivatives of a V-Bottom Planing Surface. NACA ARR No. 3L08, 1943.

Methods and charts are presented for computing stability derivatives of a longitudinally straight, V-bottom planing surface representing the forebody of a seaplane float or a flying-boat hull without chine flare. The charts for computing hydrodynamic derivatives were used in calculating the trim limit of stability for angles of dead rise of 10°, 20°, and 30°. The lower trim limit of stability of a seaplane planing on the forebody was calculated from measurements of lift, resistance, trimming moment, and wetted length of planing surfaces and was found to be in good agreement with experimental values of the trim limit of stability.

The velocity derivatives $Z_w$ and $M_w$ were computed as a function of the draft with the component due to the effect of vertical velocity on the trim neglected. A comparison of the measured results with the calculated results indicated that the trim component was of little importance and that better accuracy was obtained by neglecting it in the present calculations.

272. Benson, James M.: The Porpoising Characteristics of a Planing Surface Representing the Forebody of a Flying-Boat Hull. NACA ARR, May 1942.

A V-bottom planing surface with controllable tail surfaces was used in an investigation of the low-angle type of porpoising.

The porpoising characteristics of the planing surface were observed for different combinations of load, speed, moment of inertia, location of pivot, elevator setting, and tail area. The model was found always to be stable above and unstable below a rather well-defined critical trim and showed no tendency to porpoise in the high-angle condition that is commonly observed with flying boats. The critical trim was found to be determined mainly by the speed and load and, to a smaller extent, by the location of the pivot and the radius of gyration. Moving the pivot either forward or down or increasing

HYDRODYNAMICS
Longitudinal Stability Under Way - Low-Angle Stability

the radius of gyration lowered the critical trim. When porpoising did occur, it was observed that a decrease in the radius of gyration caused the amplitudes of oscillations in trim to increase markedly. An increase in the mass and moment of inertia without a change in the radius of gyration or other variables resulted in an increased amplitude of the oscillations. Increasing the tail area to about twice normal size did not appear to affect the critical trim.

By a comparison of these data with data from a complete model and from theoretical computations it was concluded that the effect of the wing upon the lower limit of stability at the lower planing speeds was relatively small.

273. Anon.: Porpoising Investigation. Experiments with Model No. 294-9. TM No. 46, Stevens Inst. Tech., 1941.

Tests of a model dynamically similar in all hydrodynamic respects were made to obtain a broad view of the general characteristics of lower-limit porpoising. All porpoising tests were made with special test apparatus. The model was loaded with predetermined aerodynamic forces and moments. A few tests of resistance were made.

The general phenomena of porpoising were analyzed and the effects upon porpoising of load, pitch damping rate, aerodynamic stalling moment, induced turbulence, mass moving vertically, moment of inertia, hydrofoil method of simulating air lift, waves, and initial disturbance are discussed.

Calculations of the pitch damping rate produced by the dashpot are presented in the appendix.

Longitudinal Stability Under Way - High-Angle Stability

274. Ward, Kenneth E., and Olson, Roland E.: Dynamic Tests of a Model of the Boeing 314 Flying Boat - N.A.C.A. Model 108. NACA MR, Boeing Aircraft Co., May 16, 1940.

Tank tests were made of a $\frac{9}{100}$-size dynamic model of the Boeing 314 flying boat to simulate full-scale porpoising action, to determine the effect of the position of the center of gravity and the type of landing on the porpoising action, and to determine the effect of one change in the second step and necessary changes in the main step upon the water performance. Tests were made with and without hydrostabilizers (stub wings). A few accelerated runs were made to show the stability characteristics for a simulated take-off.

The hysteresis effect in the upper trim limit of stability was discovered and the phenomenon was discussed. The hysteresis effect in the upper trim limit was present for all models except those having the deepest steps.

The position of the center of gravity had little or no effect on the trim limits of stability but changed the available trim.

Deflecting the flaps lowered both trim limits of stability but produced a diving moment which with a given amount of aerodynamic control made the upper limit more difficult to define.

When hydrostabilizers were used, the lower limit took the form of two curves enclosing a small unstable area in which the amplitude of porpoising was never large. The upper of these two curves was about the same as the curve for the lower limit without the hydrostabilizers. The hydrostabilizers tended to increase the hysteresis effect in the upper trim limit of stability.

275. Benson, James M., and Klein, Milton M.: The Effect of Dead Rise upon the High-Angle Porpoising Characteristics of Two Planing Surfaces in Tandem. NACA ARR No. 3F30, 1943.

Porpoising tests were made of three rudimentary models, each composed of two V-bottom planing surfaces in tandem fitted with a tail plane and controllable elevator. The upper and lower branches of the upper trim limit of stability were determined for three angles of dead rise ($15^{\circ}$, $22\frac{1}{2}^{\circ}$, and $30^{\circ}$) and for two depths of step (4.7 percent and 7.8 percent beam). The upper branch was found in the normal manner but, because all models failed to recover from porpoising when the trim was decreased, a different method was used to determine the lower branch. The results showed that both the upper branch and the lower branch were markedly raised by an increase in angle of dead rise from $15^{\circ}$ to $22\frac{1}{2}^{\circ}$ but were much less affected by an increase from $22\frac{1}{2}^{\circ}$ to $30^{\circ}$. The net effect of an increase in dead rise was to shift the stable range of trim to higher values without greatly altering the range between the upper limits and the lower limit. An increase in depth of step also raised the upper and lower branches of the upper trim limit.

276. Stout, Ernest G.: Hydrodynamic Landing Instability. Rep. No. ZH-013, Consolidated Vultee Aircraft Corp., Oct. 5, 1943.

Perhaps the most critical phase of any flying-boat design is the determination of the hydrodynamic stability characteristics. Hydrodynamic stability has been roughly divided into four basic types: high-and low-angle low-speed porpoising and high- and low-angle high-speed porpoising, each requiring a separate procedure of analysis and largely depending upon different basic design parameters. This paper discusses the high-angle high-speed type of instability, with particular emphasis upon the phenomenon commonly referred to among flying-boat pilots and designers as "skipping." This form of instability usually occurs during landing operations at relatively high trims and consists of a series of lunges into the air following the initial contact with the water.

The causes, procedure for analysis, and results of experimental study of this hydrodynamic phenomenon are discussed. It is concluded that high-angle high-speed instability is subject to experimental analysis and can be accurately predicted in the towing basin.

277. Locke, F. W. S., Jr., and Hugli, W. C., Jr.: A Method for Studying the Longitudinal Dynamic Stability of Flying-Boat-Hull Models at High Planing Speeds and during Landing. NACA ARR No. 4H31, 1945.

Upper-limit porpoising and skipping, which are sometimes encountered in the motion of a flying boat on the water at high speeds and high trims, were thought to have the same basic source. Investigation by similar testing procedures was therefore considered possible.

HYDRODYNAMICS
Longitudinal Stability Under Way - High-Angle Stability

A method was described for carrying out generalized experimental studies of the longitudinal dynamic stability of flying-boat-hull models. Predetermined disturbances of the motion at constant speed were introduced at an initial instant of time, simulating disturbances which might occur in actual landing or take-off maneuvers, and the effects on the subsequent motion were recorded graphically. Direct comparisons between different models, on a quantitative basis, were thus provided for.

The results of high-angle instability showed limits which were consistent with unpublished data obtained at the Langley tanks using an entirely different method. The magnitudes of the initial disturbances were found to be more important than the character of the disturbances. Within certain boundaries, increasing the magnitudes of the initial disturbances tended to cause progressively wider trim ranges of instability.

The main thesis, that upper-limit porpoising and skipping have the same basic source, was not definitely proved. The work was believed, however, to contribute to the growing body of circumstantial evidence in support of it.

278. Davidson, Kenneth S. M., and Locke, F. W. S., Jr.: Notes on Hysteresis in Upper-Limit Porpoising Based on Tests of 1/30 Scale Model of the XPB2M-1 Seaplane. Rep. No. 161-B, Stevens Inst. Tech., Aug. 12, 1941.

Preliminary tests of a $\frac{1}{30}$-size model of the Martin XPB2M-1 flying boat were made at Stevens tank to investigate the secondary upper limit (the trim at which upper-limit porpoising stops). The tests were made by locking the model at predetermined values of rise and trim, releasing it when the test speed had been reached, and recording the resultant motions of rise and trim.

The test results showed that the trims at which porpoising would stop were below the upper trim limit of stability and were $1^{\circ}$ above the trims defining the boundary between the regions in which the afterbody was wetted and clear of the water. Porpoising persisted at trims below the upper limit only when the trims from which the model was released were above the upper limit.

(See also abstracts 262 and 400.)

[redacted]

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

279. Land, Norman S., and Lina, Lindsay J.: Additional Stability Tests of a 1/8-Full-Size Dynamic Model of the Consolidated XP4Y-1 Airplane - NACA Model 143. NACA MR, Bur. Aero., March 3, 1943.

Further modifications to a $\frac{1}{8}$-size dynamic model of the Consolidated XP4Y-1 flying boat were investigated in order to improve the hydrodynamic characteristics. It was found that the landing instability was completely eliminated by increasing the depth of the V-step at the keel from 6.5 to 12 percent of the beam or by sufficiently ventilating the step. Increasing the deflection of the flaps created a large enough nose-down moment and sufficiently lightened the load on the water to cause noticeable changes in both the trim limits and limits of stable positions of the center of gravity.

Long, narrow planing fins added to the afterbody forward of the sternpost, together with a planing bottom on the tail extension, proved effective in clearing up the heavy flow of water over the tail turret and horizontal tail. In this respect this combination was superior to an extended afterbody with the same plan form as the fins. Yaw tests of this arrangement showed no large peaks in the moment-speed curves, which are characteristic of the basic model.

280. Davis, B. W.: Analysis of Results - Hydrodynamic Research Project. Rep. No. D-5558, Boeing Aircraft Co., Sept. 23, 1944.

The stability (directional and longitudinal), spray, and resistance characteristics of several configurations of the XPBB-1 flying-boat hull as obtained from Langley tank tests of similar dynamic and resistance models at normal and high gross weights are presented. Several configurations of the dynamic model were towed free in pitch, heel, and yaw to determine their effects on yaw characteristics at prehump speeds and high gross weights. The configurations tested included an afterbody extended 9 inches, a warped afterbody, an inverted V-bottom tail extension, and hydrofoils. The configurations employing the basic forebody and the extended afterbody lowered the upper trim limits somewhat and did not affect the lower limit except to lower the low-speed peak. Prehump resistance and bow spray were increased and spray on the tail was reduced. The addition of spray strips on the bow reduced spray in the propellers and flaps but increased the yaw tendency. Chine bustles near the step reduced the flap spray and were otherwise hydrodynamically satisfactory. Spray in the propellers occurred over only a short prehump speed range that may be accelerated through and can be considered satisfactory. The highest trim at which the airplane can be landed stably was lowered approximately 1°. An extended forebody used in conjunction with the extended afterbody reduced spray and lowered resistance and although it increased the yaw tendency it was the most satisfactory compromise.

An inverted V-bottom hull eliminated almost all spray but resulted in indefinite trim limits, resistance exceeding the available thrust, and directional instability. It is considered generally unsatisfactory.

Observations made of the basic configurations to determine the effects of power were in agreement with previous tank tests. An investigation was continued in an effort to confirm the belief that lower trim limits are dependent on the geometrical shape of the wetted area of the forebody. It was found that a trapezoidal area of the forebody is wetted during low-angle porpoising and a triangular area of the forebody is wetted at stable trims. The lower limit was therefore shown to be identical with the trim for a constant immersion equal to the height of the chine, as long as the afterbody was out of the water.

Tests were conducted on the basic configuration with the forebody angle of dead rise increased from 20° to 25°. Increasing the dead-rise angle resulted in improved landing stability with all loads and center-of-gravity positions, a shorter speed range during which spray occurs, and slightly higher resistance at prehump speeds. Both upper and lower limits were raised and the range of stable trims remained about the same.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

Tests were made on step fairings designed to improve the aerodynamic efficiency of the airplane. All the various fairings adversely affected the landing stability. The best fairings consisted of a shallow step and the normal afterbody with a large ventilation duct.

Tests were made to determine resistance and trimming moments for various trims and speeds. Tests were also made to determine the side force and yawing moments for various yaw angles and rudder deflections.

The resistance model forebody alone was tested to obtain wake contours and draft measurements. Data from these tests supplied information that was necessary and useful in analyzing the dynamic-model tests.

281. Bush, R.: Dynamic Model Tests in NACA Tank - 1/10-Size Model XPBB-1. Rep. No. D-2855, Boeing Aircraft Co., Sept. 24, 1940.

Tests were conducted in Langley tank no. 1 with a $\frac{1}{10}$-size dynamically similar model of the XPBB-1 flying boat to determine a satisfactory hull configuration for longitudinal stability by constant-speed runs and accelerated runs simulating full-scale take-offs and landings; to obtain specific information as to the water resistance of the final hull configurations for full-scale performance estimation; and to conduct dynamic tests of the model free in various combinations of yaw, heel, and pitch. Observations were made to determine the effects on the porpoising and resistance characteristics of changes in hull configuration, fore and aft center-of-gravity position, gross weight, and wing-flap deflection.

The tests indicated that high-angle porpoising may be virtually eliminated by deepening the main step. Low-angle porpoising is a primary function of the trim. Any change of the afterbody keel angle and the fore and aft position of the main step affects only a small change in location of the peak of the low-angle curve; the remainder of the curve remains unchanged.

The effect of gross weight on low-angle porpoising is to raise the entire curve of limiting trim against speed. No effect on high-angle porpoising was observed.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

The effect of center-of-gravity location, fore and aft, is to change the limits of trim available with elevator control. The position of the limit curves for low- and high-angle porpoising is not affected. The effect of wing-flap deflection is substantially the same as the effect of a fore and aft movement of the center of gravity.

282. Ward, Kenneth E., and Olson, Roland E.: Dynamic Tests of a Model of the XPBM-1 Flying Boat - N.A.C.A. Model 100. NACA MR, Bur. Aero., Aug. 3, 1939.

Tank tests were made of a $\frac{1}{8}$-size dynamic model of the XPBM-1 flying boat to determine the trim limits of stability and to evaluate the effectiveness of various modifications to improve the performance. Tests were made at two gross loads representing loads for the full-size flying boat of 39,000 and 44,000 pounds and at flap settings of 0°, 15°, 30°, and 60°. Air lift of the wing-hull combination was determined by towing the model at two heights above the surface of the water and measuring forces in a lift ring. The tests were made without any auxiliary devices for increasing the maximum lift coefficient of the model wing. The horizontal tail was movable only as a unit and was not remotely controllable. The technique used in these tests is discussed in detail.

It was found that a hook on the step reduced the lower trim limit of stability about 4°. A half-round block, which filled the step for 1 inch on each side of the keel, was ineffective in producing a roach which would strike the afterbody. It was hoped that this modification would improve the stability characteristics. The effect of flaps was only to change the load on the water; that is, increasing the flap deflection lowered the trim limits of stability. Some upper-limit instability was observed at a gross load of 44,000 pounds.

283. Ward, Kenneth E., and Land, Norman S.: Dynamic Tests of a Model of the XPBM-1 Flying Boat - N.A.C.A. Model 100. NACA Supp. MR, Bur. Aero., Feb. 9, 1940.

Inasmuch as tests of the XPBM-1 airplane in its original form showed that serious porpoising was experienced in take-off, changes in the form of the hull were found to be necessary. Hydrodynamic

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

stability tests of a dynamic model were made in Langley tank no. 1 to check some changes proposed by the manufacturers as a result of tank tests made at the Stevens Institute of Technology and to investigate other modifications that might improve the stability of the airplane on the water. Modifications of the form of the hull were: (1) an extension of and change in the form of the afterbody, (2) extension of the sides of the hull to give a greater beam, and (3) variations in the form and position of the step. The variations in the form of the step included a conventional transverse step with a "bent-stringer" transition, a transverse step with a transverse "breaker" step, a transverse step with a swallow-tail hook and small sponsons for locally increasing the beam, a transverse step with a transverse "breaker" step and with the chine flare filled in to form a small hook, a curved V-step, and a curved V-step with a "breaker" step and a "bent-stringer" transition.

Extending and modifying the form of the afterbody increased the trim by a small amount at low speeds before the afterbody came out of the water but apparently had no effect on the lower limit of stability. The modified form of afterbody experienced a severe yaw between speed coefficients of 2.0 and 2.6 caused by asymmetrical flow around the afterbody. It should be noted, however, that the fairing which was added to the model was poor and was not truly symmetrical about the longitudinal vertical plane.

Increasing the beam of the hull gave the most favorable result as the lower limit of stability was reduced about 1°, although a corresponding reduction in the upper limit also resulted. The spray characteristics were improved and the violence of porpoising in the unstable range was reduced.

Changing the position and the form of the step had no effect on the lower limit of stability but higher limits were obtained with the same aerodynamic control by moving the step forward. Because of the resulting increase in afterbody interference due to the shallow step and "bent-stringer" transition, a small breaker step, which broke the flow over the afterbody, was required to raise the upper limit of stability. Increasing the gross weight raised both the lower and upper limits of stability; the largest effect was on the upper limit where the increased load improved the clearance on the afterbody.

The techniques used in the tests were discussed in some detail.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

283a. Pierson, J.: Analysis of XPBM-1 Dynamic Model Tests at N.A.C.A. Engr. Rep. No. 1209, The Glenn L. Martin Co., Jan. 15, 1940.

This report presents some of the data and results given in abstract 283 and includes the curves of rise against trim referred to therein. These curves are records of the porpoising motion and give a good indication of the violence of the porpoising. The several shapes of the curves, the trim limits of stability, directional stability, spray characteristics, and testing technique are discussed.

284. Ward, Kenneth E., and Olson, Roland E.: Dynamic Tests of a Model of the XPB2M-1 Flying Boat - N.A.C.A. Model 102. NACA MR, Bur. Aero., Aug. 3, 1939.

Tests of a $\frac{1}{12}$-size dynamic model of the Martin XPB2M-1 flying boat were made in Langley tank no. 1 to determine the trim limits of stability at a full-size gross weight of 135,000 pounds and at four flap deflections. The upper trim limit of stability was found to drop sharply in a range of speeds near the low-speed peak of the lower limit. The aerodynamic lift of the wing and hull without the tail surfaces was determined. The aerodynamic lift of the wing alone was determined at several heights above the water in the tank and showed changes in the slope of the lift curve which would be expected from the ground effect.

285. Scheider, M. G.: The Effect of Keel Angle on the Resistance, Directional Stability and Longitudinal Stability of a Flying Boat Hull. Engr. Rep. No. 1824, The Glenn L. Martin Co., Aug. 24, 1943. Revised Nov. 24, 1943.

Tests were made at the Stevens tank on a $\frac{1}{30}$-size model of the Martin M-170 flying boat with angles of afterbody keel of $3^{\circ}$, $5^{\circ}$, and $7^{\circ}$. The forward half of the chine was the same for all three afterbodies. Decreasing the angle of afterbody keel lowered the low-speed peak of the lower trim limit of stability, lowered the upper trim limit, slightly improved the directional stability, lowered the trim at all trimming moments tested, and increased the high-speed resistance.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

286. Land, Norman S.: Effect of Powered Propellers on the Aerodynamic Characteristics and the Porpoising Stability of a Dynamic Model of a Long-Range Flying Boat. NACA RB No. 3E13, 1943.

Tests were made with a $\frac{1}{8}$-size dynamic model of a large long-range twin-engine flying boat to determine the effect of powered propellers on the aerodynamic and porpoising characteristics.

On a model of a long-range flying boat of conventional design, large increases in wing lift and tail moment may be expected to follow the use of powered propellers. In addition, the thrust moment considerably changes the trims assumed by the flying boat. These effects greatly influence the width of stable locations of the center of gravity.

With the present methods of determining the stability of dynamic models, exact simulation of full-size variation of thrust with speed is unnecessary although the scale thrust should, if possible, be developed by means of operating propellers of approximate scale diameter.

287. Naylor, P. E.: The Effect of Weight Variation on the Water Stability, Trim and Elevator Effectiveness of a Sunderland III Aircraft during Take-Off and Landing. Rep. No. H/Res/171, British M.A.E.E., Feb. 19, 1944.

Tests have been made to investigate the effect of weight variation on the water stability, trim, and elevator effectiveness of the prototype Sunderland III, T.9042.

Within the range of weight investigated, 43,000 to 52,000 pounds, an increase in weight with constant center-of-gravity position raises the stability limits and trim attitudes by approximately the same amount. There are indications that the upper limit is raised rather more than the lower limit and that the width of the stable region is slightly increased. The upper-limit instability is very slight on this aircraft and not well defined.

There is a progressive loss of elevator effectiveness with increase of weight but ample control remains over the weight range considered.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

288. Anon.: The Effects of Step Ventilation on the Take-Off and Landing Characteristics of a PBN-1 Flying Boat. Rep. No. 1807, NAF, Philadelphia Navy Yard, Bur. Aero., Navy Dept., April 25, 1944.

The results of a test program conducted to determine the effects of step ventilation on the take-off and landing characteristics of a PBN-1 flying boat are summarized. Because of the lack of agreement among the various pilots, definite specific conclusions in evaluating the modification were difficult to formulate. In general, the use of the maximum vent area available for test (1.69 sq ft) was believed to result in some slight improvement in landing stability.

Although not reported by all pilots, an increase in bow-down moment was indicated just after contact in landing. This increase might possibly be of some significance in rough-water operation. Although step ventilation might possibly reduce the time required for the airplane to get on the step, the tests failed to show any appreciable reduction in take-off time at a gross weight of approximately 28,400 pounds.

289. Baker, G. S., and Keary, E. M.: Experiments with Models of Seaplane Floats. Thirteenth Series. R. & M. No. 410, British A.C.A., 1919.

Experiments were made at the William Froude National Tank to develop a float suitable for use on an aerial target that would satisfy the following conditions:

(1) The float to be attached to the airplane by trunnions so that the trim of the float has no effect on the attitude of the airplane

(2) The airplane to fly off the float leaving it on the water

(3) The float to run steadily at all speeds

The two main difficulties to be overcome were diving at low speeds and porpoising at high speeds. In many cases attempts to eliminate one augmented the other. The effect on the longitudinal stability of alterations to the aft part of the afterbody were investigated.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

290. Cohn, M.: Flight Test Summary Report - Hydrodynamic Characteristics - Model XPBB-1. Rep. No. D-3854-1, Boeing Aircraft Co., March 13, 1943.

The hydrodynamic characteristics of the Boeing XPBB-1 flying boat were studied in an extended series of taxi tests. These tests, conducted at several gross weights ranging from 45,000 pounds to 80,000 pounds, consisted of constant-speed taxi runs at speeds up to take-off and accelerated runs with take-offs and landings. The data were obtained with the NACA events recorder and with the Boeing photographic recorder. The tests were made in particular to determine longitudinal stability and control, directional stability and control, spray and water flow characteristics, take-off and landing characteristics and procedures, and water resistance and water load curves.

The hydrodynamic characteristics were in general very good. Longitudinal stability on the water was very satisfactory with a wide spread between the high- and low-angle porpoising limits. When porpoising occurred it was mild and easily damped out. Directional control was adequate for turns in or out of the wind even at low water speed. Spray and flow characteristics observed were good.

Take-off characteristics were excellent, with take-off at design gross weight of 62,000 pounds consistently made in less than 43 seconds, and as low as 38 seconds. Pilot technique has considerable effect on take-off time. Overload take-offs were made at gross weights up to 80,000 pounds at which take-off became marginal.

291. Perring, W. G. A., and Hutchinson, J. L.: Full Scale and Model Porpoising Tests of the Singapore IIc. R. & M. No. 1712, British A.R.C., 1936.

Tank tests were made at the Royal Aircraft Establishment to determine the stability of the Singapore IIc seaplane on water in the planing condition. The results of tests of a $\frac{1}{12}$-size dynamic model were compared with those of the full-scale seaplane. Stability tests were difficult to perform because of the stable form of this seaplane.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

The stability limits found in the model tests were not greatly influenced by the vertical movement of the center of gravity, by overload conditions, or by increased pitching moment of inertia. The instability of the full-scale seaplane occurred at extreme attitudes and loads, at small angles with the center of gravity forward, and at large angles with the center of gravity back. These results agreed closely with the model results.

A comparison showed that the porpoising periods of the model and the full-scale seaplane were in very good agreement.

292. Garrison, Charlie C., and Pikelis, Peter S.: Hydrodynamic Characteristics of the Navy XP4Y-1 Flying Boat as Determined by Tests with the NACA Events Recorder. NACA MR No. L5H21a, Bur. Aero., 1945.

A series of take-off and landing tests were conducted on the Navy XP4Y-1 flying boat to investigate its hydrodynamic characteristics with the NACA events recorder. The tests were made at gross loads of 42,000, 46,000, and 54,000 pounds. The spray strips on the bow of the flying boat confined the bow spray to the lower third of the propeller disks at all gross loads. The spray over the tail surfaces suggested a limiting gross load of less than 54,000 pounds. Directional instability was encountered during take-offs at loads of 46,000 pounds and over when the flying boat tended to yaw to the left at speeds below hump speed. Skipping occurred during take-offs and landings and was more pronounced during the landings made at contact trims less than $7^{\circ}$.

293. Benson, James M.: Hydrodynamic-Stability Tests of a Model of a Flying Boat and of a Planing Surface Having a Small Downward Projection (Hook) on the Planing Bottom near the Step. NACA RB, Jan. 1943.

Stability tests of two dynamic models of a flying boat were made to investigate briefly the effects of adding a small projection (hook) on the planing bottom of the forebody near the step. Tests showed that a wedge-shape and a half-round projection extending the full width of the model and extending downward about eight-tenths of 1 percent of the beam had rather large effects upon all trim limits and also upon the landing stability. All trim limits were lowered, about $4^{\circ}$ at high speeds, and the tendency to skip on landing was increased. No change in the stability characteristics was noted with a half-round projection on the transom of the planing surface.

294. Anon.: Investigation of Landing Instability on the XPB2Y-3 Airplane. Rep. No. ZH-29-010, Consolidated Aircraft Corp., Sept. 22, 1942.

A short qualitative discussion of the functions of the step and afterbody in regard to landing instability, known as "skipping," is given.

Various modifications to the step were flight tested on the Consolidated XPB2Y-3 flying boat in an effort to eliminate skipping. They included an increase in step depth by a modification of the plan form of the step and ventilation of the step by ducts through the hull bottom aft of the step.

The tests showed that the most effective ducts were those near the keel and that ducts located in the rise of the step were ineffective in reducing skipping. The amount and location of ventilation ducts necessary to completely eliminate skipping produced objectionable bow-down moments. A smaller amount of ventilation, with the ducts designed for production, gave satisfactory landing stability without the bow-down moments for gross weights from 56,000 to 71,000 pounds. The results of some tests of directional stability, engine cooling, and control forces are also given. It was apparent that sinking speed had no effect upon the landing stability.

295. Garrison, Charlie C.: Investigation of the Effect of Step Ventilation on the Take-Off and Landing Performance of the Navy PB2Y-3 Flying Boat. NACA MR No. L5G19a, Bur. Aero., 1945.

The stability of a Navy PB2Y-3 flying boat was tested with the NACA events recorder during take-offs and landings in the Patuxent and St. Mary's Rivers when smooth-water conditions prevailed. Ventilation ducts were installed in the area aft of the step, in addition to those installed by the manufacturer in the production airplane. Take-offs and landings were made at nominal gross loads of 56,000, 61,000, and 66,000 pounds, with flaps deflected $20^{\circ}$ and $40^{\circ}$, with no step ventilation, and with several combinations of the additional vent

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

ducts and the manufacturer's ducts in order to determine the minimum venting area necessary to eliminate skipping. The minimum area was found to be 1.11 percent of the square of the beam. The additional ventilation had no noticeable effect on the yaw and porpoising during take-off runs, and its effect on the time and distance for take-offs and landings was small. A comparison of model and full-scale data indicates that the general conclusions of the two similar tests agree; the amount of ventilation on the full-scale flying boat, however, was slightly more than that required on the model.

296. Locke, F. W. S., Jr.: Investigation of the Effect of the Afterbody on the Porpoising Characteristics of 1/30 Scale Model of the XPB2M-1 Seaplane. Rep. No. 161-A, Stevens Inst. Tech., Aug. 7, 1941.

Tests of a dynamic model of the forebody of the Martin XPB2M-1 flying boat were made at the Stevens tank. The results of these tests were compared with those of the complete model with the same gross weight and pitching moment of inertia in order to determine the effects of the afterbody on porpoising characteristics.

The comparison showed that

(1) at high speeds the afterbody was the direct cause of upper-limit porpoising

(2) at high speeds the afterbody had no effect on lower-limit porpoising

(3) at moderate speeds (in the vicinity of the hump) the afterbody kept the trim down and thereby restrained lower-limit porpoising.

297. Benson, James M., and Freihofner, Anton: Landing Characteristics of a Model of a Flying Boat with the Depth of Step Reduced to Zero by Means of a Retractable Planing Flap. NACA RB No. 4B08, 1944.

A model of a flying boat was tested in Langley tank no. 1 to determine the landing characteristics when the depth of step was reduced to zero by means of a retractable planing flap on the forebody.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

The model exhibited exceptionally stable landing characteristics over a wide range of the location of the center of gravity and at trims from about 5.5° (afterbody horizontal) to 12° (full stall). A high-speed landing at a trim of 5° or less was stable if the model was decelerated rapidly. With less rapid decelerations the model would increase trim after landing at low trims and would take off again. Measurements of the water resistance indicated that the landing run required for the flying boat to decelerate from the landing speed to the hump speed would be decreased from 2100 feet to 1100 feet by fully retracting the step.

298. Parkinson, John B., and Land, Norman S.: The Landing Stability of a Powered Dynamic Model of a Flying Boat with a 30° V-Step and with Two Depths of Transverse Step. NACA RB No. 4B14, 1944.

Tests were made in Langley tank no. 1 of a powered dynamic model of a four-engine long-range flying boat with a 30° V-step and two different transverse steps of comparable positions and depths. The tests indicated that similar landing stability is obtained with a 30° V-step and a transverse step having the same depth as the 30° V-step at the keel.

299. Truscott, Starr, and Olson, Roland E.: The Longitudinal Stability of Flying Boats as Determined by Tests of Models in the NACA Tank. II - Effect of Variations in Form of Hull on Longitudinal Stability. NACA ARR, Nov. 1942.

Results of investigations of the longitudinal-stability characteristics of several models are considered in an attempt to arrive at general conclusions as to the effects of variations in the form of hull on these characteristics.

The lower trim limit of stability is not appreciably affected by changes in position of center of gravity, position of step, plan form of step, depth of step, angle of afterbody keel, and length of afterbody. A reduction in the angle of dead rise decreases this limit to lower trims. An increase in gross weight raises this limit to higher trims.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

The upper trim limits of stability are not appreciably affected by a change in position of center of gravity. Moving the step aft appears to raise the limits slightly. These limits are raised to higher trims by an increase in gross weight, an increase in depth of step, an increase in angle of afterbody keel, a decrease in length of afterbody, and by ventilation of a shallow step. These limits are changed by a variation in the plan form of the step in proportion to the changes in the effective depth of step and the effective position of the step.

The limits for stable positions of the center of gravity are shifted by a distance approximately equal to the distance the centroid of the step is moved. Increasing the depth of step does not appreciably change these limits. With heavier gross weights the range of stable positions for the center of gravity is reduced.

Instability in landing at high trims is reduced or eliminated either by increasing the depth of step or by ventilating the step. A depth of step of the order of eight percent of the beam has been found necessary. Large ventilation ducts located near the keel and just aft of the step are effective, but ventilation ducts near the chine are ineffective. With a depth of step of 5.5-percent beam, the landing instability of one model was not eliminated by varying the angle of afterbody keel from 4° to 8.5° and increasing the length of afterbody from 161 to 311 percent of the beam.

300. Fletcher, G. L., and Llewelyn-Davies, D.I.T.P.: Note on Some Tank Tests on the Sunderland III for Take-Off at Extreme Overload. Rep. No. Aero 1387, British R.A.E., Nov. 1943.

Tank tests were made to determine the stability characteristics and seaworthiness of the Sunderland III during take-off at an overload case of 64,000 pounds. The tests were made at the Royal Aircraft Establishment of a $\frac{1}{15}$-scale dynamic model with loads corresponding to 50,000, 56,000, and 64,000 pounds full size.

There was a marked decrease in the stability at a load of 64,000 pounds. For the highest load the propeller disks were wetted over a larger range of the low speeds and at higher speeds the tail plane was fairly heavily wetted. The tail plane may be damaged in full-size operation should landing or sudden throttling back be attempted at the maximum load.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

The stability tests were complicated by the presence of the step fairing. The fairing now in use on the full-scale airplane was known to reduce the stability but it was thought that the remaining margin of stability was adequate. On the model, the instability introduced by the fairing could be regarded as a borderline case. There were two possibilities: the instability may have been of a degree not often noticed in full-scale operation, or there might be a scale effect that made the full-scale seaplane slightly more stable than the model.

301. Hamilton, J. A.: A Note on the Water Stability of a Half Scale Sunderland Hull with a 1 in 6 Main Step Fairing. Rep. No. H/Res/158.A., British M.A.E.E., March 12, 1945.

This report is a continuation of abstract 261 and presents the effect of a 1-in-6 step fairing on the water stability of the half-scale Sunderland hull. The principal effect of the fairing has been to reduce the stable region at the hump, both in take-off and steady runs. Comparisons between small-scale (made with various tank techniques), half-scale, and full-scale stability measurements with a faired-step hull showed that:

(1) The lower limits are in fair agreement in all scales.

(2) The half-scale and full-scale upper limits seem much lower than those obtained from tank tests.

302. Chalmers, T. M.: A Note on the Water Stability of the Consolidated PBY-5 (Catalina) Flying Boat. Rep. No. H/Res/186, British M.A.E.E., Jan. 22, 1945.

The water stability in take-off and landing of the Catalina F.P. 526 has been investigated over a range of stick-fixed positions at gross weights of 27,000 pounds and 31,000 pounds. In all tests the center of gravity position was 27.6 percent standard mean chord. In every case records were made of acceleration, attitude, and elevator position. Curves of elevator effectiveness and trim limits obtained using the standard M.A.E.E. method are included.

It was found that at these weights, both in take-off and landing, the aircraft is unstable with the stick neutral. A small backward displacement of the stick from central is sufficient to trim the aircraft into the stable region in all cases. There is a marked tendency to bounce in high-speed landings with the stick back.

303. Parkinson, John B.: Notes on the Skipping of Seaplanes. NACA RB No. 3I27, 1943.

Skipping is a form of hydrodynamic instability, present during water take-offs and landings, that tosses the seaplane into the air below flying speed. Several investigations of actual seaplanes and dynamically similar models have shown that the primary cause of the instability is a large suction force on the afterbody generated by the flow behind a shallow step. The results of the investigations indicate that, for flying boats, catastrophic skipping may be avoided by the use of depths of step of from 7- to 12-percent beam. With depths of step of 5-percent beam, skipping may be alleviated by ventilation openings in the afterbody as close to the step and keel as possible. The total area of openings and ducts should be 2 percent of the square of the beam.

304. Brooke, H. E.: PB2Y-3 - Correlation of Towing Basin and Full Scale Effect of Step Ventilation on Landing Stability. Rep. No. ZH-29-011, Consolidated Aircraft Corp., June 1942.

Because of the extensive full-scale tests conducted on the XPB2Y-3, this seaplane was chosen for a comparison with model tests made at Langley tank no. 1 to determine the scale effect of step ventilation on landing stability.

The following conclusions were drawn from the comparison:

(1) The degrees of stability with various amounts of ventilation were in excellent agreement.

(2) Both model and full-scale tests showed that the vents nearest the keel were the most effective for reducing the skipping.

(3) With the elimination of skipping on the full-scale seaplane, an objectionable negative trimming moment was encountered that was not encountered with the model. This discrepancy was attributed to the difference in boundary-layer conditions between the model and the full-scale seaplane.

(4) The cushioning effect produced on the full-scale seaplane by plugging the ducts at the entrances inside the hull was not found in the model tests.

305. Smith, A. G., and White, H. G.: A Review of Porpoising Instability of Seaplanes. Rep. No. H/Res/173, British M.A.E.E., Feb. 29, 1944.

A review has been made of the evidence on take-off and landing instability of seaplanes. The basic types of porpoising and their occurrence have been examined; full-scale results have been correlated with model scale and theoretical results. Various techniques of measurement and the definitions of porpoising instability used full scale at the Marine Aircraft Experimental Establishment and model scale in the R.A.E. and Langley tanks have been discussed.

Porpoising instability has been divided into three basic types:

(1) Forebody, associated with flow over the forebody near the step

(2) Forebody-afterbody, associated with flow over the forebody and the after 20 to 30 percent of the afterbody

(3) Step instability, associated with "sticking" of the afterbody

An extensive bibliography is included.

306. Davidson, Kenneth S. M., and Locke, F. W. S., Jr.: Some Analyses of Systematic Experiments on the Resistance and Porpoising Characteristics of Flying-Boat Hulls. NACA ARR No. 3I06, 1943.

A discussion is presented of certain analyses and condensations of the test results obtained in an extensive series of systematic experiments on the porpoising characteristics of flying boats. The work is believed to simplify application of test results to practical design problems and to aid in clarifying basic concepts regarding porpoising.

It is concluded that for a given hull the stability limits are determined primarily by the net water-borne load in steady motion $\Delta$ and secondarily by the tail damping rate $M_q$. The positions of the upper stability limit and of the peak of the lower stability limit are determined by the sternpost angle and the power (dynamic lift) of the second step. The position of the lower stability limit at high speeds is determined by the dead rise and the effective warping of the forebody bottom and probably also the curvature of the forebody buttocks. The extent of the upper limit near take-off speed is governed by the effectiveness of the ventilation of the afterbody bottom in the vicinity of the main step. The stability limits are satisfactorily expressed as functions of the dimensionless criterion $\sqrt{C_\Delta}/C_V$ with the dimensionless criterion for tail damping

$$\frac{M_q}{V \frac{\rho_w}{2} b^4}$$

as a parameter where

| | |
|---|---|
| $C_\Delta$ | load coefficient |
| $C_V$ | speed coefficient |
| b | beam |
| $\rho_w$ | water density |
| V | speed |

307. Davidson, Kenneth S. M., and Locke, F. W. S., Jr.: Some Systematic Model Experiments on the Porpoising Characteristics of Flying-Boat Hulls. NACA ARR No. 3F12, 1943.

The results of systematic model experiments on the hydrodynamic characteristics of flying boats are presented. The experiments were made to develop a comprehensive view of the factors influencing porpoising and to determine their relative importance.

The following main conclusions were made:

(1) Increasing the water-borne load raises both limits of stability without materially affecting the width of the stable range. Increasing the tail damping rate lowers the lower limit at high speeds;

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

the magnitude of the effect is greatest, however, at damping rates considerably below normal.

(2) When a reasonable length is assumed, the most powerful afterbody variable is the angle between a prolongation of the forebody keel and a line joining the tip of the main step with the tip of the sternpost. Increasing this angle raises the hump trim and resistance and the upper limit of stability; if increased enough, upper-limit porpoising at high speeds will be suppressed. Increasing the step height also suppresses upper-limit porpoising at high speeds.

(3) If sufficient forebody length to provide flotation and to prevent diving at low speeds is assumed, the most powerful forebody variable is the amount of warping of the bottom in the region just ahead of the main step. Increasing the warping lowers the lower limit at high speeds but raises the hump resistance.

(4) None of the modifications considered in the experiments was successful in eliminating completely either upper-limit or lower-limit porpoising and, in general, modifications that tended to improve the porpoising characteristics tended to injure the resistance characteristics. It follows that any significant improvement in both porpoising and resistance characteristics must depend upon improving the basic parent form of the hull.

308. Locke, F. W. S., Jr.: Systematic Model Experiments on the Hydrodynamic Characteristics of Flying Boat Hulls. Effect of Changes of Afterbody Warping on Porpoising and Resistance Characteristics. Rep. No. 196, Stevens Inst. Tech., Oct. 23, 1942.

Tests at the Stevens tank were made on a $\frac{1}{30}$-size model of the Martin XPB2M-1 flying boat with the afterbody warped by altering the angle of dead rise at the sternpost, by retaining the original angle of dead rise (20°) at the step, and by maintaining straight buttock lines. The results of tests with angles of dead rise of 0° and -10° at the sternpost are presented and are compared with those of previous tests with angles of dead rise of 10°, 20°, and 30°.

The results showed that decreasing the angle of dead rise at the sternpost in the manner described had practically no effect on the lower trim limit. This decrease in the angle of dead rise, however,

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

lowered the upper trim limit, decreased the violence of lower-limit porpoising near hump speed, lowered the free-to-trim track in the vicinity of the hump, slightly decreased the hump resistance, and materially reduced the peak resistance occurring at speeds less than hump speed.

[The results are given in a condensed form as part of a more general report. See abstract 307.]

309. Locke, F. W. S., Jr.: Systematic Model Experiments on the Hydrodynamic Characteristics of Flying-Boat Hulls. Effect of Changes of Forebody Warping on Porpoising and Resistance Characteristics. Rep. No. 217, Stevens Inst. Tech., Dec. 28, 1942.

Tests at the Stevens tank were made on a $\frac{1}{30}$-size model of the Martin XPB2M-1 flying boat with the forebody warped by leaving the section at the step unchanged and varying the angle of dead rise linearly from the step to the forepoint. The profile of the keel and the plan form of the chine were the same for all five models tested. The warping varied from 0° to 10.8° per beam-length.

The results show that increasing the warping of the forebody in this manner lowers the lower trim limit slightly at hump speed and materially at high speeds, has practically no effect on the upper trim limit, increases the hump resistance, and lowers the free-to-trim track.

The two models with the least warping of the forebody (0° and 2.7° per beam-length) had pronounced tendencies to dive when run at high speeds and low trims.

[The results are given in a condensed form as part of a more general report. See abstract 307.]

310. Locke, F. W. S., Jr.: Systematic Model Experiments on the Hydrodynamic Characteristics of Flying-Boat Hulls. Effect of Changes of Planform of Main Step on Porpoising and Resistance Characteristics. Rep. No. 218, Stevens Inst. Tech., Feb. 20, 1943.

Tests were made at the Stevens tank on a $\frac{1}{30}$-size model of the Martin XPB2M-1 flying boat with a 45° V-step and a 45° swallow-tail step. The plan form of the step was altered in such a way that the planing area which was removed forward of the normal straight transverse step was added aft of it.

The tests showed that the V-step widened the stable range of trims at moderate speeds, whereas the swallow-tail step narrowed the range. The V-step suppressed upper-limit porpoising at high speeds. The plan form of the step did not appreciably influence the hump resistance, but the V-step reduced the peak resistance at speeds less than hump speed.

[The results are given in a condensed form as part of a more general report. See abstract 307.]

311. Olson, Roland E., Haar, Marvin I., and Bradford, John A.: Take-Off and Landing Stability and Spray Characteristics of Modifications of a $\frac{1}{12}$-Size Model of the JRM-1 Flying Boat - NACA Model 164. NACA MR, Bur. Aero., Sept. 8, 1944.

Several modifications of a $\frac{1}{12}$-size model of the JRM-1 flying boat were tested with and without powered propellers in Langley tank no. 2 to determine the effect of changes in hull form on the take-off and landing stability and the spray characteristics. The modifications included alterations in form of the forebody and afterbody, changes in depth of step, addition of longitudinal steps and planing flap to the forebody, and use of a single swept-back hydrofoil under the forebody just forward of the step.

Spray striking the propellers was not appreciably reduced by rotating the nacelles up $5\frac{1}{2}^{\circ}$ and thereby increasing the propeller clearance approximately 1.5 inches, by lowering the forebody bottom 0.9 inch, or by use of inboard spray spoilers. With outboard spray strips turned down approximately 20°, no spray entered the propellers at a gross load of 99.5 pounds (175,000 lb, full size).

Elevator deflections that trimmed the model above the lower trim limit at low speeds generally trimmed the model above the upper

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

trim limit at high speeds. Modifications that changed the trim limits of stability generally changed the free-to-trim tracks in the same direction. Most of the modifications caused no appreciable change in the range of positions of the center of gravity for take-off.

Landings of most of the modifications with the design depth of step were unstable. Increase in depth of step or use of longitudinal steps on the forebody greatly improved the landing characteristics. With a planing flap at the main step, the model was violently unstable. With the hydrofoil at the position tested, the model was extremely unstable at speeds just beyond the hump.

312. Daniels, Charles J.: Tank Tests of 1/10-Full-Size Model of Allied Aviation Corporation's 12-Place Float-Wing Glider - NACA Model 140. NACA MR, Bur. Aero., July 7, 1942.

Tank tests were made on a $\frac{1}{10}$-size model of Allied Aviation Corporation's 12-place float-wing glider to determine qualitatively the hydrodynamic stability and spray characteristics of the model under conditions simulating towed take-offs from the water and to evaluate the effectiveness of certain modifications designed to improve the performance. Some measurements of the towing resistance were taken and are plotted.

It was found that when a conventional step and afterbody were used in conjunction with a flap deflection of about $10^\circ$ no instability was encountered. The model was unstable in every case with $0^\circ$ flap deflection.

Float-wing arrangement

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

313. Daniels, Charles J.: Tank Tests of 1/10-Full-Size Model of Navy 24-Place Twin-Hull Seaplane Glider - NACA Model 139. NACA MR, Bur. Aero., May 29, 1942.

The hydrodynamic stability and spray characteristics of a $\frac{1}{10}$-size model of a Navy 24-place twin-hull seaplane glider were qualitatively observed and modifications to improve the performance were evaluated.

Near get-away speeds, porpoising developed which was of a dangerous character with the original design, but increasing the depth of step and angle of forebody keel improved the performance. It was found that the performance was generally improved by the use of flaps but that the use of too much up elevator was to be avoided. Towing from a bridle arrangement was most satisfactory but some satisfactory positions of a single towing point, mounted on a post between the hulls, were found.

Some towing resistance measurements were made and plotted.

314. Daniels, Charles J.: Tank Tests of 1/10-Full-Size Model of Navy XLRQ-1 12-Place Float-Wing Seaplane Glider - NACA Model 133. NACA MR, Bur. Aero., June 26, 1942.

Tank tests were made on a $\frac{1}{10}$-size model of the Navy XLRQ-1 12-place float-wing seaplane glider to observe qualitatively the hydrodynamic stability and spray characteristics under conditions simulating towed take-offs from the water. As the performance of the proposed model was generally undesirable, a conventional planing bottom was added. The spray and stability of this modification were satisfactory with a flap deflection such that the trailing edge of the flap coincided with the corner of the main step. It was found that variations in the position of the towing point have little effect on the behavior of the model.

315. Parkinson, John B., and Dawson, John R.: Tank Tests of a 1/8 Full-Size Dynamic Model of the Consolidated Model 31 Flying Boat - N.A.C.A. Model 110. NACA MR, Consolidated Aircraft Corp., May 28, 1940.

Tank tests were made on a $\frac{1}{8}$-size dynamic model of the Consolidated model 31 flying boat to investigate certain modifications of the hull designed to improve the spray and stability characteristics, especially at a gross weight of 50,000 pounds (full size). The modifications included changes in the position and depth of step, flutes and reflex chines on the forebody, planing fins on the afterbody at the sternpost, and an extension of the forebody. Limits of stable positions of the center of gravity were obtained during accelerated runs. Aerodynamic lift and moment data were obtained from tests in which the model was towed above the water surface. Stability tests were made with a $26\frac{1}{2}$- and a 100-percent increase in pitching moment of inertia, a $26\frac{1}{2}$- and a 100-percent increase in mass moving vertically, and a $26\frac{1}{2}$- and a 100-percent increase in both pitching moment of inertia and mass moving vertically.

Results of the tests to determine the limits of stable positions of the center of gravity showed that:

1. Deflecting the flaps from 20° to 40° had a large adverse effect on the stable range.

2. Moving the step forward 1 inch on the model increased the stable range.

3. Increasing the depth of step increased the stable range, chiefly by moving the after limit.

4. The effect of a planing fin on the stable range was negligible.

5. Extending the flat of the forebody forward had a small adverse effect on the stable range.

6. The effect of changes in load on the stable range was negligible.

Excess of 100 percent in moment of inertia delayed the building up of the unstable motion but tended to make small motions divergent. Excess of 100 percent in mass moving vertically caused very violent motions that started quickly. Increasing both in the same ratio

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

resulted in fairly satisfactory agreement with the behavior of the normal model and might be an acceptable procedure for models that do not possess true dynamic similarity.

A pronounced scale effect of carriage speed on the aerodynamic coefficients was obtained. A comparison of the model test data with corresponding data from tests of the full-size airplane indicated that the behavior was roughly comparable.

316. Daniels, Charles J.: Tank Tests of a 1/10-Full-Size Model of Navy XLRG-1 24-Place Seaplane Glider - NACA Model 141. NACA MR, Bur. Aero., July 14, 1942.

Tank tests were made of a $\frac{1}{10}$-size model of Navy XLRG-1 24-place twin-float seaplane glider to determine qualitatively the hydrodynamic stability and spray characteristics of the model under conditions simulating towed take-offs and to evaluate modifications designed to improve the performance.

The results of the tests indicated the following conclusions:

1. The original design was found to be dangerous because of violent yawing and porpoising at about half get-away speed and therefore is not recommended for full-size operation on the water.

2. Floats with an increased beam resulted in stable behavior throughout the planing range.

3. It was not practical to incorporate a modification that would prevent the tail booms from touching the water. Planing surfaces extending the entire length of the tail booms successfully protected the tail booms during the critical-speed range.

4. The force on the tail booms, while they were in contact with the water, and the spray on the tail and flaps were reduced by lowering the floats.

5. The addition of chine flare lowered the spray pattern and increased the yawing stability.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

6. It is questionable that a pilot could control the yawing encountered while towing from a single point at the nose of the fuselage. A bridle towing arrangement attached to the bows of the float insures stability in yaw while on the water.

7. The behavior was generally improved with the flaps down.

317. Olson, Roland E., and Zeck, Howard: Tank Tests of a 1/16-Full-Size Model of the HK-1 Cargo Flying Boat. I - Take-Off and Landing Stability, and Spray Characteristics of a Powered Dynamic Model - NACA Model 158. NACA MR, Dept. Commerce, May 19, 1944.

The take-off and landing stability and the spray characteristics of a $\frac{1}{16}$-size powered dynamic model of the proposed 400,000-pound Hughes-Kaiser flying boat were investigated in Langley tank no. 1. The range of trims between the lower and upper trim limits of stability was found to be greater for this model than for most models tested in the Langley tanks. Porpoising at high trims was easily controlled, and only a small decrease in trim was required for recovery from upper-limit porpoising. In order to obtain satisfactory take-off stability at positions of the center of gravity to be used in flight, the main step was moved 3.75 inches forward of station 63.62. The results with the step in this new position were extrapolated to the design gross load and full thrust. Satisfactory take-off stability could be obtained with neutral elevators at positions of the center of gravity as far forward as 26 percent mean aerodynamic chord and with elevators deflected -20° at positions of the center of gravity as far aft as 37 percent mean aerodynamic chord. At positions of the center of gravity between 26 and 37 percent mean aerodynamic chord, elevator control was available for avoiding porpoising or for recovering from porpoising. For satisfactory take-off stability at a forward position of the center of gravity of 20 percent mean aerodynamic chord, it would be necessary to limit the lowest deflection of the elevators to approximately -10°; if neutral elevators were to be used at this position of the center of gravity, a forward movement of the main step of about 6 percent mean aerodynamic chord would be required. The landing stability appeared to be very good over a wide range of trims and positions of the center of gravity, and only light skipping occurred when the afterbody or the tail extension was approximately parallel to the water. A change in the sinking speed of the model had no noticeable effect on the landing behavior. The spray characteristics were excellent.

318. Benson, James M., and Havens, Robert F.: Tank Tests of a Flying-Boat Model Equipped with Several Types of Fairing Designed to Reduce the Air Drag of the Main Step. NACA ARR No. L5C09b, 1945.

Tank tests were made of a flying-boat model having various types of fairing with and without ventilation ducts behind the main step to investigate the hydrodynamic characteristics of the model. All the types were designed to reduce significantly the air drag chargeable to the main step. The fairings that were made merely by adding a filler block behind the main step had an adverse effect on the take-off and landing stability. Those fairings that offered the greater restriction to the flow of air into the region under the afterbody had the greater adverse effect.

The configuration that combined the best stability with a good aerodynamic form consisted of a shallow step (depth, about 1 percent of the beam) and an adjoining ventilation aperture having an area about 7 percent of the square of the beam. With this form of step, the landing stability of the model compared favorably with that of the conventional model.

319. Parkinson, John B.: Tank Tests of the 1/8 Full-Size Dynamic Model of the Consolidated Model 31 Flying Boat with a Second Step - N.A.C.A. Model 110-M. NACA MR, Consolidated Aircraft Corp., July 12, 1940.

The results are given of additional tests of the $\frac{1}{8}$-size dynamic model of the Consolidated model 31 flying boat in Langley tank no. 1 to determine the effect of a second step on the stability characteristics. The modification consists of a second traverse step, $\frac{1}{4}$ inch deep, located $8\frac{15}{16}$ inches forward of the original point of the afterbody. Aft of the second step, the original bottom is moved up $\frac{1}{4}$ inch at the step and $\frac{1}{2}$ inch at the sternpost. Forward of the second step, the original bottom is unchanged.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

The results indicate that the modification as tested is undesirable because it produces additional exciting forces to begin porpoising and at the same time reduces the damping effect of the afterbody in large oscillations.

320. Parkinson, John B.: Tank Tests of the 1/8 Full-Size Dynamic Model of the Consolidated Model 31 Flying Boat with the Forebody Lengthened - N.A.C.A. Model 110-L. NACA Supp. MR, Consolidated Aircraft Corp., June 13, 1940.

Tests were made of a $\frac{1}{8}$-size dynamic model of the Consolidated model 31 flying boat with the forebody lengthened by increasing the spacing of the stations from bow to step. This procedure, in addition to increasing the length of the planing bottom, decreased the curvature of the buttocks and the bluffness of the water lines at the bow. The results indicated that this modification had little effect on the stable range of positions of the center of gravity and that a more important effect was an improvement in the cleanness of running.

321. Llewelyn-Davies, D. I. T. P.: Tank Tests on a Hull with the Main Step Faired in Planform and Elevation. Rep. No. Aero 2029, British R.A.E., May 1945.

Tank tests were required to find out whether the water characteristics of a hull with a main step, faired in both plan form and elevation, were comparable with those of a hull with a conventional or transverse step. Stability diagrams and spray and resistance characteristics were obtained over a large range of gross load coefficient $\left(C_{\Delta_0} = 0.616 \text{ to } C_{\Delta_0} = 1.440\right)$.

The fully faired step offers more possibility of designing a longitudinally stable flying-boat hull than does the conventional transverse step or V-step, but a hull with such a step is 5 to 10 percent less efficient hydrodynamically except at high speed. In order to avoid running at too low a trim at high speed, it is recommended for this particular form that the center of gravity should be not more than 0.46 beam ahead of the apex of the step.

The modification to the step plan form makes little difference in the main spray characteristics, but increase in all-up weight reduces wing, tail plane, and propeller clearances.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

The effect of increase in load on the porpoising characteristics is to raise both limits, with a tendency for the upper limit to rise more rapidly, but less regularly, than the lower limit. The free-to-trim attitudes also rise with increase in all-up weight.

The planing efficiency of the hull increases with increase of load, especially at high speeds. There is evidence of a second resistance hump at high speeds and also of a critical variation of planing efficiency with attitude under similar conditions.

322. Baker, C. B.: Tank Tests on a Model of the "Empire" Flying Boat. Rep. No. B.A. 1678, British R.A.E., May 1941.

Tank tests were undertaken to investigate the porpoising characteristics of a dynamic model of the "Empire" flying boat, which is a successful modern flying boat with a comparatively shallow main step. The model was tested under three conditions: take-off with flaps set at $8^{\circ}$, landing with full flaps, and take-off with full flaps. These results were followed by measurements of pitching moment on a resistance model. The cross-curves showed peculiarities not previously noticed to such a marked degree, and various modifications were made to discover the reasons for these peculiarities.

The pitching moment of a hull and also, possibly, the porpoising characteristics are affected by the air flows. This effect is considered to be caused by a high air velocity underneath the afterbody in the trough left by the forebody. When spoiler strips were placed around the model from wing to keel, a marked effect on pitching moment was produced. These strips were well clear of the water. A shield in front of the model had the same effect. Spoiler strips placed on the model were found to reduce the angle of minimum drag at a given speed.

An attempt is to be made to measure the air pressures in the gap between the afterbody and the water, and resistance tests are to be made on a number of models behind shields to investigate the effect of air flow on drag and on angle for minimum drag.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

323. Anon.: Tank Tests on the Resistance and Longitudinal Stability of Short R.2/33 Flying Boat (Sunderland). Second Addendum to Report No. B.A. 1286. Rep. No. B.A. 1286b, British R.A.E., Feb. 1938.

Because changes in the design of the Sunderland flying boat were incorporated during its construction, further tests were required on the dynamic model to determine the effect of an increase in gross weight and an aft movement of the center of gravity, the step, and the wing. Take-off and landing tests were made in calm and rough water to determine the stability and spray characteristics. The limits of stability were improved but the seaworthiness was not quite so good as it was with the original design.

324. Land, Norman S., and Lina, Lindsay J.: Tests of a Dynamic Model in NACA Tank No. 1 to Determine the Effect of Length of Afterbody, Angle of Afterbody Keel, Gross Load, and a Pointed Step on Landing and Planing Stability. NACA ARR, March 1943.

Tests were made to determine the effect of length of afterbody, angle of afterbody keel, and gross load on the limits of stable trims and on the landing characteristics of a model of a flying boat with conventional steps. In addition, tests were made of a pointed-step model. The model represented a hypothetical flying boat with a design gross load of 160,000 pounds and a wing span of 200 feet.

The tests showed that, between gross loads of 140,000 and 200,000 pounds, the stability at landing remained unchanged. Increasing gross loads raised the stable trim range to higher trims and kept the stable range constant.

The tests also showed that there is an optimum angle of afterbody keel which results in the greatest range of stable trims but not necessarily the best landing stability. The model with the highest angle of afterbody keel tested showed the best landing stability at low landing trims; whereas the model with the lowest angle was the most stable at high landing trims.

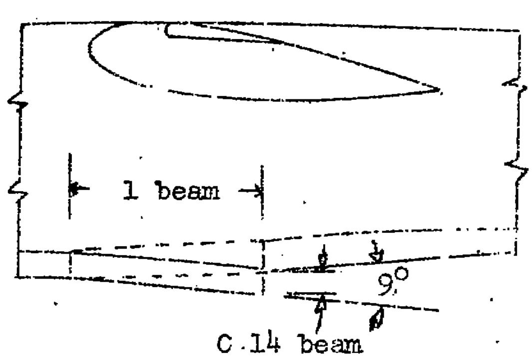
With a constant angle of afterbody keel, the shortest afterbody tested exhibited the greatest stability at landing and the widest range of stable trims.

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

The one form of pointed step investigated showed a very narrow range of stable trims but had no tendency to skip on landing at any landing trim.

325. Benson, James M., and Lina, Lindsay J.: The Use of a Retractable Planing Flap Instead of a Fixed Step on a Seaplane. NACA ARR No. 3E31, 1943.

Data are presented and discussed to show the improvements in both the hydrodynamic and the aerodynamic performance of a seaplane that could be obtained if a retractable planing flap were used instead of the conventional main step. The improvements in resistance made possible by use of a planing flap to vary the depth of step during and after take-off are of the order of 8 percent in the water resistance at the hump speed and about 2 or 3 percent in the total air drag of a long-range flying boat of current design at cruising attitude. One type of retractable flap that could be used is described and the results of hydrodynamic stability tests of a model fitted with the flap are given. The tests indicated that good stability characteristics could be provided with the planing flap for take-off and landing.



HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

326. Evans, G. J., and Shaw, R. A.: Water Performance of Sunderland K.4774 with a 1 in 6 Step Fairing. Rep. No. H/Res/142, British M.A.E.E., April 9, 1941.

Tests have been made to investigate the water-handling qualities of the Sunderland K.4774 flying boat when fitted with a step fairing of mean gradient 1 in 6. The tests were a further development of those made with 1-in-2 and 1-in-4 step fairings. Attitude, acceleration, and water-pressure measurements have been made during take-off, landings, and steady taxying runs.

There is some loss of water stability with the 1-in-6 fairing; the bouncing type of porpoise, which occurred only during taxying at high attitudes and high speeds with the 1-in-4 fairing, occurs frequently in landing with the 1-in-6 fairing. Porpoising occurs whenever the attitude at touch-down is over 3°. When the attitude at touch-down is 2° or less, the landing is quite normal.

The bouncing type of porpoise is associated with fluctuating pressures and suctions on the afterbody. There are no pressures or suctions on the afterbody during steady planing conditions or even during normal nonbouncing porpoising.

The Sunderland with the 1-in-6 fairing is not considered suitable for service use because of the instability which occurs during landing.

327. Evans, G. J., Smith, A. G., Shaw, R. A., and Morris, W.: Water Performance of Sunderland K.4774 with Step Fairing. Rep. No. H/Res/140, British M.A.E.E., Dec. 13, 1940.

Tests were made at the Marine Aircraft Experimental Establishment to investigate the hydrodynamic qualities of the Sunderland K.4774 flying boat fitted with step fairings of mean gradient 1-in-2 (fairing 1) and 1-in-4 (fairing 2).

Attitude and acceleration measurements have been made during take-offs, landings, and steady and porpoising taxying runs. Water-pressure measurements have been made at various stations over the hull bottom for the Sunderland without fairing and with the 1-in-4 fairing.

The fairings were found to have no perceptible effect on the attitudes, water moments, and water resistance of the flying boat in steady conditions, though there appeared to be a reduction in the hump speed of 3 to 5 knots with fairing 2. With fairing 2 a bouncing type of porpoise was introduced during taxying runs at high speeds and at high attitudes though there was no evidence of the stability limits being affected. The bouncing porpoise is associated with a fluctuating water flow over the afterbody, and pressure and suctions of the order of 5 pounds per square inch and -2 pounds per square inch were recorded. This porpoise was not encountered during any take-off or landing.

Ordinary porpoising is accompanied by fluctuating pressures on the forebody only. Zero pressures were recorded on the afterbody stations of the hull, without fairing and also with fairings 1 and 2, for all hydroplaning conditions during take-off, landing, and steady runs. The bouncing instability just appeared with fairing 2 at high attitudes and high speeds, but with a longer fairing it may come within the take-off and landing-attitude range.

328. Bird, J. H.: The Water Stability of the Glenn-Martin PBM-3C (Mariner) Flying Boat. Rep. No. H/Res/184, British M.A.E.E., Nov. 10, 1944.

The water stability in take-off and landing of the Mariner has been examined over a range of loadings. Tests were made at gross weights of 42,000 pounds, 46,000 pounds, 50,000 pounds, 54,000 pounds; the center-of-gravity position for all tests was 32 percent standard mean chord.

At the hump speed in take-off, the aircraft was unstable at the higher weights with the elevators neutral. Only at the two lower weights tested could the aircraft be trimmed to avoid the instability region without having the stick well back. Very little instability was experienced during landing but the aircraft has a tendency to bounce at high touch-down speeds.

329. Stout, E. G.: XPB2Y-4 - Hydrodynamic Characteristics. Rep. No. ZH-29-018, Consolidated Aircraft Corp., June 1943.

Flight tests on the Consolidated XPB2Y-4 flying boat with spray strips developed by the National Advisory Committee for Aeronautics were made at 1800, 1700, and 1200 brake horsepower per engine to investigate the hydrodynamic characteristics of the

HYDRODYNAMICS
Longitudinal Stability Under Way - Stability Characteristics

flying boat at gross loads from 58,000 to 76,000 pounds. The tests at 1200 brake horsepower per engine were made at loads up to 72,500 pounds to simulate the characteristics of the PB2Y-3 flying boat, for which the spray strips were developed. The tests at 1800 brake horsepower per engine were made at 76,000 pounds gross load only.

Spray strips reduced the height of the spray from that obtained on the PB2Y-3 flying boat without spray strips. The duration and intensity of spray in the propellers decreased with increasing acceleration (increasing power). Directional stability during take-off and general handling characteristics improved with increased power. The spray strips apparently had no effect on stability or handling characteristics.

The results of tests of center-of-gravity limits of stability are analyzed and the separate effects of gross weight, flap and elevator deflection, and acceleration are shown. The effects of acceleration are in good agreement with results of tests of a powered dynamic model of the PB2Y-3 flying boat made at Langley tank no. 1. The effects of power loading and gross weight on take-off time are shown.

Landings at all gross weights were satisfactory. No skipping was observed, which showed that the production step ventilation was adequate up to 76,000 pounds gross load.

(See also abstracts 34, 121, 134, 145, 146, 153, 180, 202, 216, 217, 220, 250, 252, 254, 255, 257, 258, 260, 277, 385, 392, and 396.)

Lateral Stability Under Way

See abstracts 281 and 401.

HYDRODYNAMICS
Lateral Stability Under Way - Heel Stability

330. Milliken, William F., Jr.: Analysis of Lateral Stability on the Water - Model 314 Airplane with Hydrostabilizers. Rep. No. D-2532, Boeing Aircraft Co., July 19, 1940.

The lateral stability of the Boeing 314 flying boat was felt to be marginal at light gross weight and at water speeds up to 20 miles per hour. Turns into or out of the wind or cross-wind taxying resulted in excessive angles of heel. Observations of the full-size flying boat indicated that, at the critical speeds, a depression in the water due to the bow wave occurred in the vicinity of the stub-wing stabilizer. Both model and full-size tests were made to ascertain the cause. Previous tests are summarized herein and conditions to be met in the design of a satisfactory hydro-stabilizer are discussed.

Data obtained at Langley tank no. 1 on the wave formation in the vicinity of the stub wings (see abstract 256) are analyzed. It is concluded that increasing the incidence of the stub wings or deflecting a flap at the trailing edge would increase the righting moment provided by the stub wings. A design for improved stub wings incorporates increased span and area, increased angle of incidence, and a bottom that is longitudinally flat instead of slightly convex downwards.

331. Coombes, L. P., and Bottle, D. W.: Notes on Stubs for Seaplanes. R. & M. No. 1755, British A.R.C., 1936.

Purpose of investigation.- Information was required on the relative merits of a flying boat fitted with stubs and wing floats for lateral stabilization on the water. The necessary tank tests were made at the Royal Aircraft Establishment, and the tests of the hull with stubs were broadened in scope so as to give data of general use.

Range of investigation.- Preliminary tests were made to determine the type of hull suitable for stubs, and then systematic tests to find the effect of changes of position and shape of the stubs were carried out. Wind-tunnel tests were also made to complete the investigation.

The results were supplemented by data from other tanks, and a comparison was drawn between the performance of the same seaplane fitted with stubs and with wing floats.

HYDRODYNAMICS
Lateral Stability Under Way - Heel Stability

Conclusions.-

(a) The shape of the hull to which stubs are attached is relatively unimportant and a special design of hull is not required when this form of stabilizer is used.

(b) Some unfavorable wave interference between the stub and hull will occur at low speeds, but the position of the stub can be chosen so that the effect on the take-off is negligible. The effect of the different variables is given in the form of curves.

(c) The relative merits of stubs and wing floats will depend on the design, but provided the stubs are set to give their optimum performance it appears that:

(1) The weight of a stub design will be from 0.5 percent to 3 percent greater than the weight with wing floats.
(2) The take-off time is approximately equal.
(3) The lateral stability obtainable with stubs is less than that given by wing floats.
(4) Longitudinal stability (porpoising) is unaffected by the change from stubs to floats.
(5) The maximum speed in flight is about equal.
(6) From the experience gained in other countries, notably Germany, the seaplane with stubs appears to be more seaworthy.

332. Fehlner, Leo F.: Some Design Criterions for Wing-Tip Floats. NACA MR No. L5H02, Bur. Aero., 1945.

An analysis is made of the performance expected of wing-tip floats for seaplanes and a design procedure is developed for determining the buoyancy and dynamic lift requirements of tip floats. This design procedure can be adjusted to the individual requirements of each class of seaplane and is thus more flexible than formulas that previously have been applied to the design of tip floats for all classes of seaplanes. The design procedure was applied to the design of the wing-tip floats for a particular seaplane, and it was found that the wing-tip floats could displace about half the volume which they displaced when designed according to previous criterions.

HYDRODYNAMICS
Lateral Stability Under Way - Heel Stability

A discussion of the loads on the supporting structure of the wing-tip float during planing at large drafts is included.

The results indicated that satisfactory lateral stability would be maintained if the wing-tip floats were designed to produce forces no larger than necessary for resisting the most probable maximum upsetting moment. Any forces greater than these are considered hazards because forces due to excessively large wing-tip floats either increase the probability of structural failure or unnecessarily burden the seaplane with additional weight. Wing-tip floats designed according to the procedure presented in this analysis should be supported by structures designed to withstand the maximum forces and moments on the wing-tip float during its complete submergence at high velocity.

(See also abstracts 34, 204, and 316.)

Lateral Stability Under Way - Directional Stability

333. Pierson, John D.: Directional Stability of Flying Boat Hulls during Taxiing. Jour. Aero. Sci., vol. 11, no. 3, July 1944, pp. 189-195.

Increased loading of flying boats to the maximum operational limit has led to a renewed interest in the directional stability characteristics of hulls. Cases have arisen wherein yawing at speeds below the hump has prevented take-off. Also, cross-wind operation is often impossible below hump speed because of weather-cocking. At these low speeds rudder effectiveness is slight and unbalanced power would reduce accelerating forces, with the net result that inherent directional instability is uncontrollable.

Investigation of these characteristics was made on several flying-boat models in the Experimental Towing Tank, Stevens Institute of Technology. Curves of yawing moments against yaw angle were determined at various model speeds and loadings. Assembling of these individual stability curves on a grid of loading plotted against speed formed the composite charts of directional stability, which show the over-all picture of the hull directional stability. The charts exposed regions of severe instability on the basic hull forms.

HYDRODYNAMICS
Lateral Stability Under Way - Directional Stability

Tests of the forebody alone demonstrated its responsibility for the low-speed moderate instability and showed that the flow along the rounded afterbody lines caused the severe discontinuities near hump speed. Modifications to straighten or separate this flow on the afterbody were tested in a similar manner. The modifications included skegs along the keel and under the tail cone and chine strips and side steps near the second step. The side steps were most effective on the models and were applied full scale. Flight-test results, while qualitative in extent, indicated substantial improvement in the taxying performance of the airplane.

334. Pierson, J.: Model PBM-3 and 4 - Towing Basin Tests to Improve Directional Stability below Hump Speed. Engr. Rep. No. 1648, The Glenn L. Martin Co., July 30, 1942.

Undesirable yawing characteristics of the PBM-3 at speeds below the hump first became apparent in attempted cross-wind taxi runs. Later, during high-overload water tests conducted by the Navy Trial Board at Norfolk, Va., pronounced directional instability became the limiting factor in the determination of the maximum gross weight for take-off.

Concurrently with the flight tests of the ship the behavior of the $\frac{1}{22}$-size model was being studied at the Stevens Institute of Technology Towing Tank. Model tests in a yawed and heeled attitude of the original hull form revealed a very unstable region just below hump speed in both the upright and the heeled positions of the model.

A number of modifications to the hull were tested. These included skegs, spray strips, and vertical steps on the sides of the afterbody. The vertical steps were the most successful. The unstable range was eliminated in the model tests by the application of these side steps on the afterbody and they were recommended for test on the airplane.

335. Gott, J. P.: Note on the Directional Stability of Seaplanes on the Water. R. & M. No. 1776, British A.R.C., 1937.

This investigation was made to elucidate the problem of the directional stability and control of flying boats on the water.

HYDRODYNAMICS
Lateral Stability Under Way - Directional Stability

The motion of a flying boat on the water has been investigated by making step-by-step calculations. The calculations refer to two hulls. Some of the data were obtained from existing tank tests, while special tests were made where necessary.

In order to investigate the directional controllability of flying boats on the water, it was found sufficient to compare the air rudder moment with the yawing moment due to yaw in the water, provided that the moments are measured about suitable body axes and at the running attitude of the hull. A high running attitude is favorable to directional stability. It is suggested that occasional uncontrollable directional instability occurs when a flying boat runs at an unusually low attitude. The low attitude might be associated with a fast landing or with porpoising about the lower limit of stability.

336. Schairer, G.: Report of Towing Tests of the Model XPBB-1 on Lake Washington during October & November, 1940 - Model XPBB-1. Rep. No. D-2939, Boeing Aircraft Co., Nov. 15, 1940.

Tests of a $\frac{1}{10}$-size dynamic model (see abstract 281) of the Boeing XPBB-1 flying boat were made on Lake Washington at Sand Point Naval Air Station to determine qualitatively the directional stability characteristics and behavior of the model under rough water conditions with various wind conditions. The model was towed by a bifurcated wire bridle attached to the leading edge of the wing outboard of the nacelles and was otherwise free. Wire rings were fitted to simulate the propeller disks. The stability and spray characteristics were satisfactory. A revised tip float, shorter than the original but having the same volume, was tested on the model and found to be the more satisfactory. The directional stability of the model was much better than that of a model of the Boeing 314 tested previously. Porpoising was not affected by angle of yaw.

(See also abstracts 153, 179, 234, 257, 280, 283, 285, 290, 292, 294, 295, 316, 329, and 330.)

AERODYNAMICS
General

337. Wenzinger, Carl J., and Bowen, John D.: Tests of Round and Flat Spoilers on a Tapered Wing in the NACA 19-Foot Pressure Wind Tunnel. NACA TN No. 801, 1941.

Several arrangements of round and flat spanwise spoilers attached to the upper surface of a tapered wing were tested in the Langley 19-foot pressure tunnel to determine the most effective type, location, and size of spoiler necessary to cause a large reduction in the lift on the wings of large flying boats when moored. The effect of the various spoilers on the lift, the drag, and the pitching-moment characteristics of the tapered wing was measured over a range of angles of attack from zero to maximum lift. The most effective type of spoiler was found to be the flat type with no space between it and the wing surface. The chordwise location of such a spoiler was not critical within the range investigated, from 5 to 20 percent of the wing chord from the leading edge. A flat spoiler 2.5 percent of the mean aerodynamic chord in height would probably be sufficient to prevent a moored flying boat from lifting off the water.

(See also abstracts 22 and 64.)

Propulsive Arrangements

338. Chillson, C. W.: Reversible Pitch Propellers as Applied to Water Handling of Multi-Engine Flying Boats. Jour. Aero. Sci., vol. 7, no. 7, May 1940, pp. 269-275.

Brief mention is made of several reversible-pitch propeller applications. Some of the problems encountered in the water handling of multiengine flying boats are discussed. The use of reversible propellers is proposed as an aid to maneuvering, and tests are cited in which it was found possible to turn a four-engine flying boat in as small a radius as desired and to stop or to back against the wind. Adaptation of a conventional electrically controllable propeller for reverse-pitch operation is illustrated schematically and described briefly. While engine cooling imposes limitations to protracted high-power operation in reverse pitch, experience to date indicates that these limitations need not be exceeded in normal operation.

AERODYNAMICS
Propulsive Arrangements

Engine overspeeding while the blades are going through zero angle is prevented by engine and propeller inertia at moderate throttle settings and with available rates of pitch change. Limitations imposed by propeller blade and retention stresses and the effect of forward tilt thereon are discussed. No ill effects of negative thrust are to be expected on either engines or engine mounts.

(See also abstracts 56, 57, 268, 311, and 363.)

Forces and Moments on Hulls and Floats

339. House, R. O.: The Aerodynamic Drag of Five Models of Side Floats. N.A.C.A. Models 51-E, 51-F, 51-G, 51-H, and 51-J. NACA TN No. 680, 1938.

The drag of five models of side floats was measured in the Langley 7- by 10-foot tunnel. The most promising method of reducing the drag of floats indicated by these tests is lowering the angle at which the floats are rigged. The addition of a step to a float does not always increase the drag in the flying range, floats with steps sometimes having lower drag than similar floats without steps.

Making the bow chine no higher than necessary might result in a reduction in air drag because of the lower angle of pitch of the chines. Since side floats are used primarily to obtain lateral stability when the seaplane is operating on the water at slow speeds or at rest, greater consideration can be given to factors affecting aerodynamic drag than is possible for other types of float and hull.

340. Hartman, Edwin P.: The Aerodynamic Drag of Flying-Boat Hull Models as Measured in the N.A.C.A. 20-Foot Wind Tunnel - I. NACA TN No. 525, 1935.

Measurements of aerodynamic drag have been made in the Langley propeller-research tunnel on a representative group of eleven flying-boat-hull models constructed originally for testing in Langley tank no. 1. Four of the models were modified to investigate the effect of variations in over-all height, contour of deck, depth of step, angle of afterbody keel, and the addition of spray strips and windshields.

The results of these tests, which cover a pitch-angle range from -5° to 10°, are presented in a form suitable for use in performance calculations and for design purposes. The drag of the "cleanest" model was compared with that of an airship hull at approximately the same Reynolds number. The results showed that:

(1) The drag coefficient, based on maximum cross-sectional area, decreased with increase in the height of hull - the drag, of course, actually increased.

(2) The minimum drag of a rounded-deck hull was 20 to 25 percent less than that of a flat-deck hull of the same over-all height.

(3) The drag coefficient was increased approximately 20 percent by the addition of a 1-inch step (5.9 percent beam). Pointed steps appeared to have a higher drag than transverse steps; the higher drag was due probably to the increased depth.

(4) Up to an angle of about 6°, the effect of the angle of afterbody keel on drag was practically negligible, but the drag increased quite rapidly for larger angles.

(5) The spray strips, which were about 2 percent of the beam in width, increased the minimum drag of the model by approximately 8 percent.

(6) The drag of a 15° undercut windshield was approximately 20 percent more than that of an ordinary windshield.

(7) The drag coefficient of an airship hull model was about 0.052, whereas the minimum drag coefficient was 0.092 for the cleanest hull model. The drag of the flying-boat model could be reduced about 43 percent if practical considerations were disregarded.

341. Kohler, M.: Aerodynamic Forces and Moments of a Seaplane on the Water. NACA TM No. 728, 1933.

Wind-tunnel tests were made on a model of a twin-float twin-engine biplane seaplane over a plate representing the surface of the water. The tests were made for angles of pitch of -1.5°, 3°,

AERODYNAMICS
Forces and Moments on Hulls and Floats

and 8°, angles of heel of 0° and 5°, and angles of yaw from 0° to 360°. Measurements were taken on a six-component balance and the results were transformed to axes fixed with respect to the seaplane.

342. Coombes, L. P., and Clark, K. W.: The Air Drag of Hulls. Aircraft Engineering, vol. IX, no. 106, Dec. 1937, pp. 315-321, 328.

The design of a flying-boat hull is a compromise between the usually conflicting requirements of good performance on the water and in flight. A large amount of information is available on the effect of form on the water characteristics of hulls but little is known about the corresponding effects on air drag. In an effort to bridge the gaps existing in such data, a systematic investigation was made at the Royal Aircraft Establishment.

The work was divided into two broad divisions: the effect of altering the main dimensions of a hull, and the effect of altering the detailed features. Over-all length-beam ratios from 5.5 to 10.0 were used in the investigation. [The dimensions were evolved approximately by the relationship between load coefficient $C_\Delta$ and length-beam ratio $L/b$

$$C_\Delta \propto \left(\frac{L}{b}\right)^{2.54}$$

in order to maintain uniform seaworthiness.]

From changes in the cross-section of the hull, it was found that

1. A narrow beam is favorable in every way except for accommodation. The limiting ratio of over-all length to beam, beyond which it is not economical to go is probably between 9 and 10.

2. A deep hull is a good feature.

3. A deep V-section has a lower air drag than a flat V-section, but if an angle of dead rise of 20° to 25° at the main step is exceeded the water performance is seriously impaired.

AERODYNAMICS
Forces and Moments on Hulls and Floats

4. A hollow V-section is good for water performance but entails a small loss in drag.

5. Projecting chines and chine strips are very bad. Flush chines should not be rounded.

The effects of some of the features necessary for good water performance are

1. Adding a V-shape planing bottom and chines increases the air drag 10 percent.

2. Making the planing bottom discontinuous in angle has no detrimental effect, but actual breaks or steps increase the air drag appreciably.

3. Curving up the afterbody to give water clearance for the tail plane increases the air drag considerably.

Some of the effects of steps are

1. Main steps are best made of straight transverse form for air drag. All other plan forms of step have a higher drag except a 60° V (apex pointing aft).

2. Rear steps tapering gradually to a vertical knife edge have the lowest air drag.

3. Fairings for steps have a bad effect on water performance unless they are either made retractable or leave a shallow step across the hull. Guide vanes to deflect the air round the steps are useless.

From the investigations of lateral stabilizers, it was found that

1. Wing-tip floats that retract into the engine nacelles have a lower air drag than fixed floats.

2. Retraction of the wing-tip floats outward to the wing tips is not worth the mechanical complication except to prevent oscillations in flight at high speeds.

3. Stubs have a high air drag.

AERODYNAMICS
Forces and Moments on Hulls and Floats

In general, the drag of a normal hull of good form is about 30 to 40 percent greater than the drag of a pure streamline shape of the same volume, and this drag is increased a further 20 to 25 percent by the need for lateral stabilization. It is possible to reduce the hull-plus-stabilizer drag to some 15 percent above the ideal, but the actual figure will in general be higher because of seaworthiness requirements.

343. Jones, R., and Pell, G. N.: The Air Resistance of Flying Boat Hulls. R. & M. No. 461, British A.C.A., 1918.

Models of nine flying-boat hulls were tested in the 7-foot wind tunnel of the National Physical Laboratory. The lift and drag at various angles of pitch were measured for one model, and the drag at one angle of pitch was measured for all other models. The tests were made over a range of speeds.

344. Wilson, Herbert A., Jr., and Lipson, Stanley: Clean-Up Tests of the SC-1 Airplane in the Langley Full-Scale Tunnel - TED No. NACA 2348. NACA MR No. L5A31a, Bur. Aero., 1945.

An investigation of the SC-1 airplane has been conducted in the Langley full-scale tunnel to determine modifications that will increase its maximum speed and to evaluate the maximum lift, the stalling characteristics, and the stability and control. Only a preliminary summary of the drag clean-up results is presented in this report. These results show that the maximum speed of the airplane can be increased approximately 21 miles per hour by making relatively minor modifications and refinements to the detailed design of the airplane.

[Of special interest are the relative magnitudes of the drag increments of the floats and the excrescences and unsealed gaps on the fuselage. Removal of the main float and tip floats would add 35 miles per hour to the top speed.]

345. Pannell, J. R., and Griffiths, E. A.: Determination of the Forces and Moments Acting on a Model of a Flying Boat Hull. R. & M. No. 223, British A.C.A., 1915.

Wind-tunnel tests were made at the National Physical Laboratory on a model of a flying-boat hull. The variation of longitudinal and

AERODYNAMICS
Forces and Moments on Hulls and Floats

normal forces and pitching moment with angle of pitch and the variation of longitudinal and lateral forces and yawing moment with angle of yaw were determined. The variation of drag with speed was also measured.

346. Jones, R., Bell, A. H., and Brown, A. F.: Drag Measurements on a Model of a Flying Boat Hull in the C.A.T. 7784, Ae. 2540, British A.R.C., June 8, 1944.

Air-drag measurements were made on a model of a flying-boat hull and a typical landplane fuselage at several angles of incidence and over a wide range of Reynolds number. Provision was made to fair the step in the hull with six different types of fairing. The object of the investigation was to provide data for designing a hull having a drag comparable with a typical fuselage. The effect of fairing the chine at the forward end of the hull was examined as also was the effect of a cabin on the fuselage. A comparison with similar tests conducted in 1938 is included.

The results show that a hull form can be evolved having a drag only 6 percent higher than that of a fuselage. At the expense of an increase in drag of only 5 percent over the best fairing tested, a type of step can be designed which will probably avoid the increased weight and complications of a retractable fairing.

The results of the earlier experiments were confirmed.

There is little change in drag coefficient $C_D$ with incidence at positive angles. ($C_D$ is based on surface area.)

Fairing the chine has little effect; it causes a decrease of less than 0.0001 in $C_D$.

The ratio of the $C_D$ of the fuselage with cabin to that of the hull with straight fairing is 0.94 and the corresponding ratio from the earlier tests is 0.91 (no fin or cabin).

The most effective fairing is the straight fairing and by use of such a fairing it is possible to design a hull having only 6 percent more drag than a fuselage of similar surface area. The actual reduction in drag obtained by adopting the straight fairing is about 25 percent in the present instance. The area of the step is about 9 percent of the cross section of the hull.

347. Millikan, Clark B.: First Additional Wind Tunnel Tests on a 0.068 Scale Model of a Revised Version of the Boeing Model XPBB-1 Flying Boat without and with Running Propellers. GALCIT Rep. No. 307, Sept. 24, 1941.

This report describes tests of a 0.068-scale model of a revised version of the Boeing XPBB-1 flying boat made in the GALCIT 10-foot wind tunnel. Tests without running propellers were made at a wind speed of about 161 miles per hour, a dynamic pressure $q = 60$ lb/ft$^2$, and a Reynolds number of 1,230,000. Tests with running propellers were made at a dynamic pressure of 10.24 pounds per foot$^2$.

The investigation was divided into the following broad groups:

Conventional Investigation without Running Propellers

(1) Effects of miscellaneous modifications, chiefly on lift and drag

(2) Horizontal tail surface and flap effects

Investigation with Running Propellers

(3) General description of procedure

(4) Flap and tail effects with various constant powers

(5) Visual flow observations using tufts

348. Göthert, B., and Ribnitz, W.: Der Luftwiderstand von Schwimmern und Flugbooten. Luftwissen, Bd. 6, Nr. 3, March 1939, pp. 101-107. (Available as British Air Ministry Translation No. 1042.)

From systematic examination of available literature on the aerodynamic qualities of hulls, the following conclusions are drawn:

AERODYNAMICS
Forces and Moments on Hulls and Floats

(1) The factor of aerodynamic efficiency of well-designed hulls with smooth surfaces, that is, the ratio of the drag of a streamline form of similar fineness to the drag of the hull applied to existing forms, is between 0.55 and 0.62 for floats and between 0.60 and 0.65 for boat hulls.

(2) A float form of low flying drag possesses a rounded deck angle, reverse bow sheer, and easily rising bilge line.

(3) The principal drag factors of well-designed hulls compared with streamline forms include the design of the step (about 10- to 15-percent increased drag) and the stern sheer (about 15-percent increased drag).

(4) The drag of the main step can be estimated with a step drag coefficient $c_{w_{St}} = 0.20$ (related to the step transverse area); the drag of the second step is usually exceptionally small.

(5) Retractable step fairings with a length not exceeding six times the step depth almost completely eliminate the step drag.

(6) The aerodynamic efficiency factor of land-aircraft fuselages is about 30 percent higher than for hulls of usual design. Step fairing of flying-boat hulls with low stern sheer, however, may be expected to bring the efficiency factor of flying-boat hulls to within about 8 percent of the efficiency factor of land-aircraft fuselages.

349. Naylor, P. E.: Note on Air Lift and Drag of Sunderland. Rep. No. H/Res/181, British M.A.E.E., Oct. 13, 1944.

An investigation has been made of the aerodynamic efficiency of the Sunderland flying boat.

The results indicate that the cleanness of the Sunderland is similar to that of many four-engine landplanes but, due to the large surface area, the total skin friction and form drag is higher.

AERODYNAMICS
Forces and Moments on Hulls and Floats

350. Simmons, L. F. G., and Cowley, W. L.: Report on the Aerodynamic Properties of Seaplane Floats. Part I. The Blackburn Float. Part II. The Air Department Main Float for the Short Seaplane. R. & M. No. 285, British A.C.A., 1919.

Wind tunnel tests were made at the National Physical Laboratory of models of two floats formed by adding planing surfaces and chines to streamline bodies of revolution. The minimum drag of these floats was low in comparison with the minimum drag of other floats previously tested. The effect of removing the planing surfaces and chines of the tail of one of the floats was to increase the lift slightly without appreciably altering the drag and to make the pitching moment less positive at angles of pitch up to 13°.

351. Fullmer, Felicien F., Jr.: Tests of a 1/40-Scale Wing-Hull Model and a 1/10-Scale Float-Strut Model of the Hughes-Kaiser Cargo Airplane in the Two-Dimensional Low-Turbulence Pressure Tunnel. NACA MR, Dept. Commerce, Sept. 24, 1943.

Aerodynamic tests were made of a $\frac{1}{40}$-scale wing-hull model and a $\frac{1}{10}$-scale float-strut model of the proposed arrangement of the Hughes-Kaiser cargo airplane in the Langley two-dimensional low-turbulence pressure tunnel.

The results of the wing-hull model tests showed that the incidence of the hull had an appreciable effect upon the angle of zero lift, the slope, and the maximum lift characteristics. Minor modifications to the hull had little effect on the lift characteristics of the model.

The model as originally tested showed unusually low drag coefficients for all angles of incidence, and the addition of a step fairing lowered these drag coefficients 7.5 percent. The addition of wing fillets caused only small changes in drag. The added chine flare caused small increase in the drag coefficients of this model in the high-speed condition. A moderate increase in the drag coefficients was obtained with transition fixed just aft of the bow.

The results of the float-strut model tests showed that changes in incidence did not appreciably affect the drag coefficients of the model. An increase in drag-coefficient increment of over 30 percent was obtained with a step in the afterbody of the float. The addition of the spray strips and the cove caused an increase in drag which was greater than that caused by the step.

352. Bryant, L. W., Irving, H. B., and Cowley, W. L.: Tests of a Model Seaplane. R. & M. No. 199, British A.C.A., 1915.

Wind-tunnel tests were made at the National Physical Laboratory of a model of a three-engine, four-float seaplane with twin fuselages to determine: the effects of stabilizer and elevator settings on the pitching moment; the variation of lift, drag, and pitching moment with angle of pitch; the hinge moments of the elevators and rudders; and the effects of various modifications on lift and drag. Tests were also made of the biplane wings alone, of the air flow through the radiators, of one of the fuselages, of modifications to the tail of the main floats, and of the hinge moments of a balanced elevator.

353. Diehl, Walter S.: Tests on Airplane Fuselages, Floats and Hulls. NACA Rep. No. 236, 1926.

A compilation of air-drag data on airplane fuselages, nacelles, airship cars, seaplane floats, and seaplane hulls has been prepared. The discussion of the data includes the derivation of a scale correction curve to be used in obtaining the full-scale drag. Composite curves of drag and lift-drag ratio for floats and hulls are also given.

354. Cowley, W. L.: Tunnel Tests on High-Speed Seaplanes. Aircraft Engineering, vol. II, no. 20, Oct. 1930, pp. 247-248.

Tests were made in the N.P.L. wind tunnels to obtain data for design and for estimating the performance of three twin-float seaplanes: the Supermarine S.5, the Gloster IV, and the Short Crusader. Effects of various modifications for improving the drag and pilot's field of view were tried. In some cases data were required for calculations on stability and control of the airplanes. Tests were also made to find the trimming position for the tail.

AERODYNAMICS
Forces and Moments on Hulls and Floats

A large interference effect between the floats and the rest of the model, about 7 percent of the total drag, was noticed on the Crusader.

A model land chassis was made and substituted for the float system of the Gloster IV model. Tests showed that the minimum drag of the seaplane decreased from 54.3 pounds to 50.6 pounds when the test speed was changed from 60 to 100 feet per second, whereas the drag of the landplane remained practically constant at approximately 50.5 pounds over the same speed range. The maximum lift full-scale at 100 feet per second, however, was found to be about 2250 pounds in the case of the seaplane and only about 2060 pounds in the case of the landplane. It would therefore appear that, as at present designed, a seaplane is aerodynamically superior to a landplane for high speed.

355. Benson, James M.: The Value of Retracting Wing-Tip Floats on Flying Boats Compared with That of Retracting the Landing Gear on Landplanes. NACA MR, Bur. Aero., June 5, 1944.

The apparent reversal in recent years in the trend of the design of tip floats and a return to fixed arrangements suggests the need for a reexamination of the air drag of floats, together with an examination of the hydrodynamic characteristics of shapes that would be suitable for retraction. This report is a review of the results of wind-tunnel tests of outboard floats and landing gear, together with an outline of a few arrangements of floats that may provide practical solutions of some of the problems that have been encountered in earlier arrangements of retractable floats. From these test results, a comparison is made of the air drag of the fixed wing-tip floats of a flying boat and the air drag of a well-faired, nonretractable landing gear of a landplane - both airplanes having about the same performance and having a gross weight of about 65,000 pounds. It is concluded that the full retraction of tip floats would justify as much penalty in weight and expense as does the retraction of landing gear.

356. Clark, K. W., and Cameron, D.: Wind Tunnel and Tank Tests on the Drag of Seaplane Hulls. Rep. No. B.A. 1406, British R.A.E., May 1937.

Reasons for inquiry.- The tests were undertaken to investigate the effect on air drag of various systematic modifications to a seaplane hull. The work is a continuation of that described in abstract 186.

AERODYNAMICS
Forces and Moments on Hulls and Floats

Range of investigation.- A hull was developed from an airship form by bending the tail upwards until the deck line of the afterbody was straight and by adding the V-bottom and steps in stages. Drag measurements were then made on hulls of various beams, faired steps, pointed steps, tail turned up or down, chines overhung or rounded off and altered angle of dead rise. The models were all 5 feet in length and were tested at wind speeds of 120 and 200 feet per second. Some tank tests were also made.

Conclusions.- Large variations in drag result from changes in hull form. Overhanging the chines and turning up the tail may increase the air drag of a normal hull at 0° incidence by about 60 percent, corresponding to perhaps 16 percent of the total drag of a modern flying boat. Rounding off the chines, fairing the steps, and turning down the tail may reduce the hull drag by 30 percent and the total drag of the aircraft by 8 percent. The V-bottom represents about 10 percent of the drag of the hull at 0° incidence, and half this drag may be saved by a small radius on the chines without causing serious deterioration in water performance. The steps cause 16 percent of the drag, and the whole step drag may be saved by fairings extending behind the steps to six times the step depth. These fairings would increase the water resistance but could be made to retract for take-off by hinging them along the rear edge. A pointed rear step is of advantage but not a pointed main step. An acute V-bottom has a lower drag than an obtuse V-bottom.

357. Conway, Robert N., and Maynard, Julian D.: Wind-Tunnel Tests of Four Full-Scale Seaplane Floats. NACA ARR No. 3G15, 1943.

Wind-tunnel tests of four full-scale seaplane floats were made to determine the aerodynamic characteristics of the floats and to evaluate several drag-reducing refinements. The floats were designated Edo model OS2U-2-68F, Edo model OS2U-2-68, Vought-Sikorsky model OS2U-1, and Edo model 62-6560. The first two floats differed only in such external details as flush rivets. The last-named float was of the type used on twin-float installations.

The variation of lift, drag, and pitching moment with pitch angle is presented for each float. In addition, tabulated results show the change in drag of the floats caused by the presence of various float fittings and also the reduction in drag made possible by the application of step fairings and other less extensive modifications. The effect of decreasing the depth of the step is also shown.

The results of these tests indicated that a radical change in the float design was necessary to obtain a worth-while reduction in float drag. A step fairing which might conceivably be made retractable reduced the drag of the Edo 68F float more than 10 percent, and a 4-foot tail extension on the blunt-stern Edo 62-6560 float reduced the drag 8 percent. The flow of air over the floats was shown to be so turbulent that minor refinements, such as flush rivets and recessed fittings, would not appreciably reduce the drag. The accumulated reduction in drag resulting from the use of several minor refinements might, however, be sufficient to justify their employment on a float to be used on a high-speed airplane.

358. Millikan, Clark B.: Wind Tunnel Tests on a 0.068 Model of a Revised Version of the Boeing Model XPBB-1 Flying Boat without and with Running Propellers. GALCIT Rep. No. 297, April 7, 1941.

Tests of a 0.068 model of a revised version of the XPBB-1 flying boat were made without running propellers at a wind speed of about 174 miles per hour, a dynamic pressure $q = 70$ lb/ft$^2$, and a Reynolds number of 1,330,000. Tests with running propellers were made at a dynamic pressure of 12.5 pounds per foot$^2$.

The investigation was divided into the following broad groups:

Conventional Investigation without Propellers

(1) Wing-alone measurements
(2) Effects of model build-up and miscellaneous modifications
(3) Horizontal tail surface and flap effects
(4) Effects of turbulence

Investigation with Running Propellers

(5) General description of apparatus and testing technique
(6) Effects of propeller rotation and horizontal tail setting

AERODYNAMICS
Forces and Moments on Hulls and Floats

359. Millikan, Clark B.: Wind Tunnel Tests on a 0.068 Scale Model of the Boeing Model XPBB-1 Flying Boat without and with Running Propellers. GALCIT Rep. No. 290, March 14, 1941.

Tests of a 0.068-scale model of the Boeing XPBB-1 flying boat were made without running propellers at a wind speed of about 174 miles per hour, a dynamic pressure $q = 70$ lb/ft$^2$, and a Reynolds number of 1,270,000. Tests with running propellers were made at a dynamic pressure of 12.5 pounds per foot$^2$.

The investigation was divided into the following broad groups:

Conventional Investigation without Propellers

(1) Wing-alone measurements
(2) Effects of complete model build-up and miscellaneous modifications
(3) Horizontal tail surface and flap effects

Effects of Running Propellers

(4) General description of apparatus and testing technique
(5) Motor calibration
(6) Motor and propeller operating characteristics
(7) Tail surface effects at various constant powers

360. Roumiantzeva, E.: Wind-Tunnel Tests with Airplane Fuselages and Flying-Boat Hulls. Rep. No. 190, Trans. CAHI (Moscow), 1935.

The results of tests of six model airplane fuselages and four model flying-boat hulls are given, as obtained in the CAHI 1.5 m (4.9 ft) wind tunnel T-3 at a mean airspeed of 35 m per second (78 mph). Lift and drag coefficients as well as pitching-moment coefficients against angle of attack were measured and the dependence of the lateral force, the drag coefficient, and the yawing-moment coefficient on the angle of yaw was determined.

The tests showed that

1. The less the variation of the lift, drag, and pitching-moment coefficients with the angle of attack $\alpha$ and of the lateral force, the drag coefficient, and the yawing-moment coefficient

with the angle of yaw $\gamma$, the smoother are the lines of an airplane fuselage or of a flying-boat hull.

2. The comparative curves of the lift and drag coefficients against the angle of attack and of the lateral force and the drag coefficient against the angle of yaw for the same fuselage show a greater increase of the lateral force and the drag coefficient with $\gamma$ than the lift and drag coefficients with $\alpha$; this fact may be attributed to the flattened form of the sides of all the fuselages, that is, to the difference of areas exposed to the air stream in case of lateral or longitudinal movements of the fuselage. Several hulls with cross sections extended in the longitudinal direction show opposite features.

3. The change of the drag coefficient with the angle of attack although less than the change of the drag coefficient with the angle of yaw is nevertheless comparatively large. The drag of several fuselages in normal flight ($\alpha = 8^\circ$ to $10^\circ$) is almost twice as great as their drag at zero angle of attack. Therefore there is no reason to introduce the drag of the fuselage as a constant value in an airplane design, equal to its value at $\alpha = 0^\circ$ and constant for all flight conditions.

4. The fuselage form has a negligible effect on the magnitude of lift and drag coefficients.

5. The variation of the lateral force and drag coefficient with the fuselage form has shown that within the usual flight angles a smooth elliptical form is better than a sharp-edged one.

6. At small angles of yaw the center of pressure is usually located in the nose of the fuselage or the hull, which corresponds to a negative (that is, destabilizing) yawing moment; therefore, at $\gamma = 0$ most fuselages are unstable and only after being moved at some angle (from $6^\circ$ to $8^\circ$) on either side do they become stable.

7. The analysis of the pitching-moment coefficient against the angle of attack shows a greater or smaller extent of instability of fuselage at small angles of attack.

For the reason of asymmetry of the model and the presence of cut-outs, windshields, radiators, and steps, there is a pair of forces giving in some cases a positive and in some cases a negative

AERODYNAMICS
Forces and Moments on Hulls and Floats

pitching moment. The center-of-pressure curve against angle of attack shows a discontinuity and has two branches passing into infinity, the asymptote of which is a vertical straight line, corresponding to the angle of attack at which $C_n = 0$.

(See also abstracts 121, 138, 154, 155, 156, 157, 173, 174, 183, 186, 204, 257, 286, and 331.)

OPERATION
General

361. Stout, Ernest G.: Report on Temporary Field Duty in the Pacific Area. Consolidated Vultee Aircraft Corp., Nov. 20, 1944.

This report on recent temporary field duty by Mr. Stout provides a survey of flying-boat operation, maintenance, and facilities at the principal Naval Stations, both combat and transport, in the following areas: Hawaiian Islands, the Marshalls, the Marianas, the Admiralty Islands, Australia, New Caledonia, the New Hebrides, and the Line Islands.

Mr. Stout had the opportunity to deliver three talks to 90 officers and men in the Hawaiian area. These talks consisted of a broad discussion of the general hydrodynamic theory of porpoising and skipping and methods for recognizing the various forms of instability and the application of preventive and corrective measures.

The consensus of opinion seemed to be that a faster and more seaworthy flying boat is needed. It was thought that rescue service is of sufficient importance to necessitate a specially designed aircraft. Jet-assisted take-off would be invaluable in offsetting present handicaps of rough water and short lagoons. It was especially noted that serious hull corrosion was absent even though many of the airplanes observed had been anchored in salt water for long periods of time. There was a general objection to the handling of flying boats at most bases; however, transport squadrons have developed handling much further with floating "U" docks, padded rearming boats, and motor launches. Cargo handling facilities are still inadequate, primarily because of the small cargo hatches provided and the number of such hatches.

The development of simple and direct water handling facilities is considered by the author to be the most important single item for improving the utility and operation of flying boats.

(See also abstracts 2, 8, 64, and 337.)

OPERATION
Piloting

362. Wagner, F. D.: Emergency Take-Offs in the Open Sea. Navy Dept. Aviation Circular Letter No. 9-44, Feb. 7, 1944.

Waves in the open sea are of two kinds: those which are formed by local wind and are described as "sea" and those which arrive from a distance and are commonly called "swells." The former are irregular, short-crested, steep, frequently breaking waves. The latter are regular and undulating with long, rounded, widely separated crests. As swells travel over the ocean, the velocity of the swells actually increases while their height diminishes. The wave velocity bears a constant relationship to the wave period and wave length.

By taking advantage of the velocity of waves, a considerable increase in the acceleration of a seaplane is possible.

Some guiding principles are set forth to aid pilots in making emergency open-sea take-offs in heavy swells regardless of the direction of the wind:

1. Lighten the aircraft by jettisoning as much removable weight as safety and balance permit.

2. Start take-off with the swell at the stern, that is, headed down swell.

3. Apply power immediately before the crest of a swell has reached the aircraft. This procedure results in very rapid acceleration of the aircraft due to both the application of power and the surfing effect of the swell.

4. The aircraft should be on the step prior to climbing on top of the swell which was next ahead at the start of the take-off.

5. The aircraft should be air borne when on top of the first swell next ahead. If not, make a small arc in the take-off in order to ride the crest of the swell for a longer period.

Take-off into the wind is always to be preferred if swells are small and irregular or crossing.

Down-swell take-offs are not to be attempted except under stress of emergency conditions.

OPERATION
Piloting

363. Hutchinson, J. L.: Note on the Value of Reversible Pitch Propellers on Seaplanes. Rep. No. H/Res/178, British M.A.E.E., July 17, 1944.

Reversible pitch propellers provide a solution of many of the marine problems which have impeded the development and handicapped the operation of seaplanes. The braking qualities of these propellers are of special value in handling seaplanes on the water and facilitate mooring-up, unmooring, and maneuvering operations. The mooring-up and unmooring procedure can be carried out by a rigger at the side door and in full view of the pilot (as on Coronado). As a result, it is considered that cleaner bow lines could be designed for flying boats. Reversible pitch propellers appear, in fact, more necessary on seaplanes than on landplanes with their wheel brakes for ground control.

A propeller with quickly reversible pitch would also provide braking in emergencies. The Coronado propellers, however, do not reverse rapidly enough for this purpose. The time required to reverse pitch is 15 seconds. The time required to change from reverse pitch to fine pitch is 10 seconds.

364. Anon.: Open Sea Seaplane Operations. Rescue Advisory Memo. No. 066, Air Sea Rescue Agency (Washington), 1945.

Tests of a PBM-3C airplane were conducted in the open sea off the coast of southern California by the Coast Guard Air Station, San Diego, to:

(1) Study general sea, swell, or wind conditions affecting safe landings, taxying, and take-off
(2) Determine what heading with respect to swell, sea, and wind is best for open-sea landing and take-off
(3) Determine what flying technique is best for open-sea landing and take-off and what hazards are involved
(4) Study the possibilities of jet-assisted take-off for use in rough-water operations
(5) Observe the capabilities and limitations of the PBM-3 airplane in rough-water operations

A total number of 54 landings and take-offs were made, which gave 108 pilot-copilot experiences and impressions. Detailed descriptions of taxying, take-off, and landing procedures under various sea conditions are offered. The usefulness of jet-assisted take-off units is emphasized.

The PBM airplane is found to be especially suited to rough-water work. The engine of the PBM-3 airplane is inadequate for open-sea operation but it is probable that the PBM-5 airplane, which has a more powerful engine, will not experience the engine difficulties or failures of the PBM-3.

365. Cram, Jack R., and Brimm, Daniel J., Jr.: Part Four - Seaplane Flying. Civil Pilot Training Manual. C.A. Bull. No. 23, CAA, U.S. Dept. Commerce, Sept. 1940, pp. 218-238.

Instructions are given for pilots on the operation of seaplanes while on the water and in the air. The topics discussed include nomenclature, taxying, sailing, approach and departure, take-offs, landings, and cross-country seaplanes flying. The topics are discussed in some detail and an attempt is made to include all conditions under which operation might be necessary.

Three attitudes for taxying are discussed: idling (speed less than 8 mph), nose up, and planing. In the first two attitudes the control should be held full back. In order to start planing (speed between 20 and 30 mph), the control is held full back and throttle opened wide. As the seaplane shows a tendency to rock over on the step, the controls should be moved forward to neutral or somewhat forward of neutral. During planing a very slight back pressure should be held. A tendency to porpoise should be corrected by back pressure on the controls. Turns at planing speeds should be made cautiously, especially if wind exceeds 40 miles per hour or if waves are high.

As a general rule if the wave height exceeds one-fifth the length of the floats, take-off should not be attempted except by the most expert seaplane pilots. For take-off in glassy water, "rocking" to get on the step or taxying across the wake of surface boats is advocated. It is stated that the water resistance is reduced by one-half near get-away if one float of a twin-float seaplane is lifted out by use of the ailerons.

The best attitude for landing is stated to be that at which step and sternpost touch simultaneously, but smooth landings may

OPERATION
Piloting

be made in almost any position if the control is being moved back at contact. A landing in waves should always be made in the full-stall position. In glassy water a power stall should be used, starting at an altitude of about 50 feet and touching at a speed about 15 percent above the full stall. Sinking speed should be regulated by use of the throttle. Emergency landing on the ground should be made with the keel of the floats parallel to the surface and up elevator applied immediately after landing.

366. Benson, James M.: Piloting of Flying Boats with Special Reference to Porpoising and Skipping. NACA TN No. 923, 1944.

The various types of hydrodynamic instability, including porpoising, skipping, and yawing, that may be encountered during take-off or landing of a flying boat are described and the piloting technique required for efficient take-offs and landings is discussed. Suggestions are made for assisting a pilot to become familiar with the take-off and landing qualities of a flying boat that is new to him.

367. MacDiarmid, D. B.: Report on PBM-3S Offshore Landing Tests. USCG ND11 Let. No. 601, Jan. 10, 1945, attached to Bur. Aero. Let. Feb. 19, 1945, (Aer-E-23-WSD, C05114) sent down with NACA Form No. 187 dated Feb. 24, 1945, TLKS ah, Enc.

The proposed program for offshore tests originally provided for a succession of tests with the sea conditions becoming progressively worse. To date, the tests have included take-offs and landings in swells varying from 3 feet to 8 feet in height. During these tests the angular displacement between the direction of motion of the swell and the direction of the wind varied from 0° to 180°. Two fixed cameras were rigged in the airplane to record instrument readings and the pilot's view of the sea. A flight analyzer was installed in the forward bunk room. A buoy was constructed with which the height of the swells was measured.

Conclusions: First, for the PBM flying boat, the wind condition may be safely ignored if under 20 knots, and the selection of the landing course should be governed by the sea condition.

OPERATION
Piloting

Apparently cross-wind landings with a moderate wind are comparatively safe. Second, down-swell landings and take-offs can be very comfortable and not in the least dangerous. Third, cross-wind take-offs with anything more than a light wind should be avoided because of difficulty of maintaining heading. Fourth, landings and take-offs into the swell should be avoided wherever possible because of excessive pounding. Fifth, landings should be made to the leeward of the objective in the water, as down-wind and cross-wind taxying is hazardous at best.

(See also abstracts 63 and 338.)

Seaplane Bases

368. Anon.: Blackpool Airport. Flight, vol. XLVI, no. 1865, Sept. 21, 1944, p. 318.

An airport proposed by the town of Blackpool, England, has been approved by the Air Ministry and passed by their own local Council. The complete scheme, which comprises a transocean air terminal for landplanes and an adjacent lagoon for flying boats, has been planned in relation to the town's general development scheme; and it is estimated that the project costing around L30,000,000 will be developed to its full capacity, the handling of more than 50,000 passengers a day, in 15 years.

The landplane runways are to be arranged in a triangular manner with auxiliary runways for taxying. The runways are to be capable of taking aircraft more than twice the size and weight of the biggest bombers and transports of today.

The proposed lagoon for flying boats is to be 4 miles in diameter and to abut on the Southport shores of the Ribble estuary, and its administrative buildings are to be connected to the main aircraft terminal by a road and rail tunnel under the river. Meteorological conditions in this locality are excellent for flying.

OPERATION
Seaplane Bases

369. Grieme, F. H.: The Establishment of a Restricted Area for Seaplane Operation. Tech. Development Note No. 32, CAA, U.S. Dept. Commerce, Jan. 1944.

The historical background of one establishment of a restricted area for seaplane operations in the United States is presented and guidance for future establishment of other such restricted areas is offered.

The size of seaplane operating areas as determined in the investigation should be as follows:

(1) For seaplanes having gross weights of 40,000 to 100,000 pounds, two or more operating lanes $2\frac{1}{2}$ miles long, 600 feet wide, and 10 feet deep with a turning basin at each end 2000 feet in diameter and 10 feet deep

(2) For seaplanes having gross weights over 100,000 pounds, lanes 5 miles long and 15 feet deep, lane widths and basin diameter to be increased to a lesser proportion, the diameter not more than 3000 feet

(3) For seaplanes having gross weights of 10,000 to 40,000 pounds, operating lanes $1\frac{1}{2}$ miles long, 350 feet wide, and 6 feet deep

(4) For small seaplanes, an effective length of 3500 feet in all directions and a depth of $4\frac{1}{2}$ feet

370. Schildhauer, C. H.: Nature Deals a Trump to Marine Airport Designers. Aviation, vol. 44, no. 8, Aug. 1945, pp. 106-110.

Since the world abounds in natural water areas which will enable year-round operation of flying boats, the engineering of the flying-boat port is simplified and hence fundamental economics are indicated. The building, docking, and patrol requirements have been considered and three schemes for seadrome layout have been presented with detailed specifications for cable-connected lane markers.

OPERATION
Seaplane Bases

For flying boats of 200,000 pounds, channels approximately 2 miles long, 800 feet wide, and 10 feet deep have been considered ample.

The flying boat of adequate size, economically operated from natural water areas, may well be the solution in enabling broad world use of fast, modern air transport.

Seaways

See abstracts 362 and 364.

RESEARCH
General

371. Davidson, Kenneth S. M.: Concerning a Standard Series of Flying-Boat Hull Models. TM No. 70, Stevens Inst. Tech., 1943.

A program has been arranged by which a standard series of seaplane hulls may be developed. This series is intended to be analogous to "Taylor's Standard Series" of ship models, which has received wide acclaim. The deduction of primary variables to be considered, the general testing procedure to be followed, and the manner of presenting the results are discussed in detail.

372. Pabst, Wilhelm: The Development of Floats and Equipment for Research in Promoting It. NACA TM No. 740, 1934.

An attempt is made to present, from the point of view of a research engineer, research methods that would facilitate the development of seaplane floats while avoiding errors and minimizing expenditures. Resistance, drifting and maneuvering, and landing impacts of floats are discussed, and apparatus for investigating those factors is described.

373. Babio, Felipe Lafita: Experimentación de cascos y flotadores de hidroaviones. Revista de Aeronautica, vol. III, no. 32, Nov. 1934, pp. 587-592.

Data taken from experiments made abroad with seaplane hulls and floats are discussed in detail. The necessity for model tests in obtaining data on seaplanes is emphasized. The principle of dynamic similitude is described and the use of Froude number is explained. As the Reynolds number effect becomes increasingly important with very small models, models much larger than those that can be used for tests in the El Pardo tank are shown to be necessary if good results are to be obtained. The specific and the general resistance test methods are described and the usefulness of the load-resistance ratio in comparing models of different scales and in facilitating take-off calculation is pointed out.

The El Pardo tank in Spain, the tank in Paris, France, the Hamburg tank in Germany, the tank at Farnborough, England, and the Langley tank in the United States are briefly described. The need of a high-speed tank for Spain is stressed.

RESEARCH
General

374. Stout, E. G.: Proposal for Hydrodynamic Research Program. Rep. No. ZH-014, Consolidated Vultee Aircraft Corp., Nov. 1943.

A hydrodynamic research program has been proposed to establish a more thorough coordinated understanding of the basic fundamentals of seaplane development. The program involves a study of length-beam ratio, a study of hydrofoils and hydrofoil systems, and a study of hull lines designed for spray control. The tests are to be made on both resistance and dynamic models in a towing basin and on free-flight dynamic models in smooth and rough water and in quartering waves.

375. Garner, H. M.: Seaplane Research. Jour. R.A.S., vol. XXXVII, no. 274, Oct. 1933, pp. 830-863.

The most important problems in the design of seaplane floats are hydrodynamical and structural. The hydrodynamical problems require measurements of resistance, stability, and seaworthiness; the structural problems require measurements of total loads, hull pressures, and loads in the structural members. Methods are given for measuring the water resistances of models and of full-scale seaplanes, and a discussion of the scale effects on the various measurements is presented. Of particular interest is the DVL method of measuring resistance in which levers transmit the loads to calibrated oil dashpots. Various methods of achieving longitudinal and lateral stability are considered. Seaworthiness is mentioned and it is noted that a high angle of dead rise results in increased directional instability at low speeds. The American, British, and German devices for measuring loads and hull pressures are described in detail and some of the results are cited.

376. Fletcher, G. L.: Some Preliminary Measurements of the Boundary Layer Conditions on Models in the R.A.E. Seaplane Tank. TN No. Aero 1472, British R.A.E., July 1944.

Measurements were made of the velocity gradient in the boundary layer at the step of a V-shaped wedge. No bow or afterbody was represented and the dead rise was constant. The surface conditions were standard for the tank model, and the effects of artificial aids to turbulence were tried. Results were analyzed in terms of the velocity gradient and loss of momentum in the boundary layer.

RESEARCH
General

Results show that considerable laminar flow probably exists on tank models below a Reynolds number of $10^6$ at low speeds near the keel. The proportion of laminar entry flow decreases rapidly toward the chine and can also be considerably reduced by use of a 30 s.w.g. wire behind the leading edge. This method is not readily applicable to model tests because the position of the wire would require alteration for each test condition. The use of sand may be possible but requires more tests to determine a suitable roughness and also the value of the additional drag.

(See also abstract 172.)

Equipment

377. Locke, F. W. S., Jr.: Comparison of Stevens and N.A.C.A. Porpoising Tests of the XPB2M-1 Flying Boat. Rep. No. 216, Stevens Inst. Tech., Dec. 23, 1942.

Discrepancies between the trim limits of stability, especially in the lower limit at high speeds, of the Martin XPB2M-1 flying boat as determined by tests at the Langley tanks on a $\frac{1}{12}$-size model and at Stevens tank on a $\frac{1}{30}$-size model are attributed to deflections of the Stevens testing apparatus. These deflections increased in magnitude with speed and resulted in recorded trims somewhat higher than the actual trims. The testing apparatus has been braced to eliminate the deflections. The trim limits obtained on the modified testing apparatus and the trim limits previously obtained and now corrected to allow for the deflections are in good agreement with the trim limits obtained at the Langley tanks.

378. Jacobs, Eastman N., and Abbott, Ira H.: Experiments with a Model Water Tunnel. NACA TN No. 358, 1930.

A model water tunnel built in 1928 by the National Advisory Committee for Aeronautics to investigate the possibility of using water tunnels for aerodynamic investigations at large scales is described. The model tunnel is similar to an open-throat wind tunnel but uses water for the working fluid. Results are given of tests of the tunnel and also of some observations made with model airfoils in the tunnel to study the phenomenon of cavitation. It is concluded that a water tunnel does not offer a convenient method of making aerodynamic investigations at large scales. A large water tunnel would be of value chiefly for use in the study of cavitation.

379. Coombes, L. P., and Perring, W. G. A.: The Farnborough Seaplane Tank. Aircraft Engineering, vol. VI, no. 61, March 1934, pp. 63-66.

The history of tank testing is briefly reviewed and the R.A.E. seaplane tank at Farnborough is introduced. The tank construction and operation are extensively described and illustrated by sketches. The testing equipment and procedures are discussed and future programs are suggested. [See abstracts 385, 387, and 401.]

380. Kempf, G., and Sottorf, W.: The High-Speed Tank of the Hamburg Shipbuilding Company. NACA TM No. 735, 1934.

A description is given of the high-speed tank of the Hamburg Shipbuilding Company. The details of design and operation are discussed and several photographs and charts are included.

The new tank is 1056 feet long, 16.4 feet wide, and 8.2 feet deep to the brim. The tank has a flat bottom and is independent of the rail track. The total accelerated carriage weight is 11,350 pounds, 8160 pounds of which are supported by the driving wheels. The carriage is designed for a top speed of 65.6 feet per second with a test run of 590 feet. The carriage is powered by two direct-current shunt motors of 40 kilowatts driving the front wheels and has an auxiliary accelerating device consisting essentially of drop weight. The carriage is braked over a distance of 164 feet by five sets of brakes:

(1) Main air brake manually operated from the carriage

(2) Automatic trip on the air brake

(3) Electrodynamic breaking

(4) Drop-weight application of brake shoes

(5) Rubber-rope arresting gear

RESEARCH
Equipment

Tests have been made to determine the effects of wall and depth on resistance.

381. Cremona, C.: Investigations and Tests in the Towing Basin at Guidonia. NACA TM No. 892, 1939.

The principal object of the Hydrodynamic Section at Guidonia is the investigation of the forms and the study of the behavior of the hulls and floats of seaplanes. Resistance tests of the general type are conducted on floats and hulls and performance tests of dynamically similar models of specific designs are made to determine the best location of wing struts, horizontal tail plane, position of the propellers, etc., in relation to the size of the wave formation. The towing basin and equipment have been discussed in detail, some results of tests have been given, and a summary of the type of work - both theoretical and experimental - that is under way has been presented.

The towing basin is 460 meters (1518 ft) long, 6 meters (19.8 ft) wide, and 3.50 meters (11.55 ft) deep. Two towing carriages are used, both of which run on pneumatic tires. The larger carriage, which weighs 6000 kilograms (13,200 lb), is a bridge-type carriage. Each of the four wheels is powered by a 25-horsepower direct-current electric motor. With this power, the carriage can attain a maximum speed of 20 meters per second (65.6 fps) and a minimum speed of 5 centimeters per second (0.164 fps). The smaller carriage, which weighs 2000 kilograms (4400 lb), is a monorail towing carriage with one or two parallel cantilever arms, which extend to the center line of the tank and at the end of which is suspended the recording apparatus. The carriage runs on three wheels and has a 100-horsepower motor with which a speed of 40 meters per second (131.2 fps) can be reached within a minimum interval of 10 seconds; intermediate speeds can be obtained by fine regulation. A compressed-air catapult is available for use when very high speeds must be attained in the shortest possible time. With a maximum pressure of 50 atmospheres, a speed of 100 meters per second (328.1 fps) may be attained.

The forces are measured by a three- or six-component balance. The hydraulic unit that is used in the dynamometer indicates loads as high as several hundred kilograms with extremely small error and with a negligible deflection.

RESEARCH
Equipment

General resistance data from tests of a twin-float seaplane (Cant Z 505) hull are presented for a single hull and for five different float spacings: namely, 3, 4, 5, 6, and 7 multiples of the beam. The characteristic dimension that was used in the conventional displacement coefficients based on Froude's law was taken as a mean beam and had a value of $\sqrt[3]{2}$ times the beam of one float.

Tests of motor boats and torpedo-shaped bodies are briefly discussed.

Some of the theoretical investigations being conducted are: (1) the pressure distribution on geometrically simple bodies, (2) the propagation of small wave motions, and (3) planing and submerged surfaces.

382. Truscott, Starr: The N.A.C.A. Tank - A High-Speed Towing Basin for Testing Models of Seaplane Floats. NACA Rep. No. 470, 1933.

A description is given of the high-speed towing basin of the National Advisory Committee for Aeronautics, usually referred to as Langley tank no. 1. The purpose of this piece of equipment is to enable the committee to provide information and data regarding the performance of seaplanes on the water analogous to the information furnished concerning the performance of airplanes in the air.

The tank and its equipment, together with the method of operation, are described, and the type of work done is illustrated by data from two typical tests. The first test was to determine the effect on the take-off performance of a model of a flying-boat hull of fitting the step with "hooks" of three different heights, and the second, to determine the effect on the take-off performance of the same model of fitting the bottom just forward of the main step successively with two and three flutes of two different depths. In each case the performance with the alterations is compared with the performance of the model with a plain bottom. The distinctive discontinuities found in the speed-resistance curves at hump speed are a notable feature of the results of these tests.

RESEARCH
Equipment

383. Lamb, H.: On the Effect of the Walls of an Experimental Tank on the Resistance of a Model. R. & M. No. 1010, British A.R.C., 1926.

Calculations have been made to estimate the effect of the walls of an experimental tank on the resistance of a towed model; the tank should be wide enough to reduce wall-effect errors to the limits of accuracy imposed by other experimental factors.

At low speeds, when the squares of the relative velocities may be neglected, the wave resistance will be unaffected provided the tank is sufficiently wide for the reflected waves from the sides to fall clear of the stern of the model. If the width of the tank is twice the length of the model (length-beam ratio of 5), the effect of the walls is to increase the frictional resistance, which is assumed to vary as the velocity squared by less than 1 percent. If the width of the tank is equal to the length of the model, the corresponding increase in frictional resistance is between 5 and 6 percent.

The results of the calculations were confirmed by tests made in the William Froude National Tank and in Messrs. Short's experimental tank.

384. Smith, A. G.: Proposals for New Seaplane Model Testing Facilities. TN No. Aero 1543, British R.A.E., Nov. 1944.

The case for new seaplane testing facilities is examined and proposals made for a new seaplane testing tank. An appendix is added on a design for a proposed new ditching tank for free-flight landing tests of seaplanes and landplanes.

A new seaplane tank is proposed that will be 6000 feet long by 25 feet wide by 7 feet deep. This tank should have separate bridge-type carriages for resistance-model and dynamic-model tests, the first to be run on steel-tired wheels, the second on pneumatic rubber-tired wheels. Both carriages should attain an operational speed of 100 feet per second and a reserve speed of 125 feet per second. The carriages would consist of faired open-ended boxes in which correct air-flow conditions could be obtained. A working volume 9 feet deep, 25 feet wide, and 30 feet long would be provided. The normal dynamic and resistance models would be made with a 10-inch beam and the special resistance models would be made with beams as large as 30 inches.

RESEARCH
Equipment

385. Coombes, L. P.: Research in the R.A.E. Tank. Jour. R.A.S., vol. XXXIX, no. 297, Sept. 1935, pp. 807-825.

The R.A.E. tank is 650 feet long, 9 feet wide, and $4\frac{1}{2}$ feet deep and has a maximum carriage speed of 40 feet per second. Testing apparatus has been developed to accommodate both resistance and dynamic models. It is interesting to note that resistance data are taken during accelerated runs.

Tests were conducted to determine the limitations of the tank from the standpoint of wall interference, depth effect, and scale effect. Models with lengths up to 1.5 times the width of the tank could be tested provided that the water were as deep as the model was long. Twin-float arrangements were found to exhibit little interference when placed close together (1/2 length). Depth had some effect on the hydrodynamic characteristics at very low speeds, but in normal accelerated runs a flying boat would experience little effect of depth in shallow water. The smaller models, scaled by Froude's law, gave higher resistance than larger models largely because of the frictional component.

Several tests were made to determine the advantages of using stubs instead of wing-tip floats for lateral stability. The penalty for using stubs as against tip floats for the design tested was about $2\frac{1}{2}$ miles per hour at a top speed of about 150 miles per hour.

Some preliminary porpoising tests were made on dynamic models with an approximately similar aerodynamic structure.

386. Perring, W. G. A.: Some Notes on Factors Affecting Seaplane Tank Design. TN No. Aero 1544, British R.A.E., Nov. 1944.

The factors affecting tank design have been discussed, and it is concluded that the future needs of seaplane development and research may require a tank with

| | |
|---|---|
| Maximum speed, fps | 90 |
| Duration of maximum speed conditions, sec | 20 |
| Working acceleration of carriage | 0.2g |
| Upper limit of acceleration | 0.3g |
| Length of tank, ft | 3400 |
| Width of tank, ft | 18 |
| Depth of water, ft | 6 |

RESEARCH
Equipment

Control of both the steady speed and the rate of acceleration of the carriage is recommended. The advantage of a carriage system that permits tests at constant draft is stressed. A form of tank design is proposed that will reduce carriage weight to a minimum and at the same time eliminate any serious disturbance to the air in the neighborhood of the model under test.

387. Coombes, L. P., Perring, W. G. A., and Johnston, L.: The Use of Dynamically Similar Models for Determining the Porpoising Characteristics of Seaplanes. R. & M. No. 1718, British A.R.C., 1936.

The methods of testing dynamic models and the apparatus used at the R.A.E. tank are discussed.

The results of a wind-tunnel investigation of the air flow about the carriage indicated that the model should be towed from a point several feet in front of the carriage. Although the change in air velocity due to the carriage is negligible, the downwash in the neighborhood of the wings and tail necessitates an increase in the angle of incidence of these aerodynamic surfaces. For the usual tests the models are free to rise and trim but are restrained in roll and yaw. Accelerated take-offs are often omitted as they are considered of little importance, and landing tests with the equipment described are not entirely satisfactory.

The models are limited in span to 7 feet and may be further limited in size by the top speed of the carriage, which is 40 feet per second. The hulls are constructed of hollowed balsa, strengthened at the chines by aluminum spraying. The structure is kept as light as possible to obtain scale trimming moments of inertia. It is believed that, although aerodynamic surfaces are necessary, they need not be accurately reproduced. Simplification of construction has been accomplished by:

(a) Using equivalent rectangular wings of constant section in place of wings having other plan forms, sweepback, taper, or dihedral

(b) Having tail plane of rectangular plan form and constant section, the elevators being integral and not arranged to move separately

RESEARCH
Equipment

(c) Omitting rudder and fin unless the fin is required for carrying the tail plane

(d) Simplifying the sections of fuselage or parts of a hull above the water line

(e) Omitting propellers, engine nacelles, and all struts not required for structural reasons

388. Coombes, L. P., Perring, W. G. A., Bottle, D. W., and Johnston, L.: Tests on the Wall Interference and Depth Effect in the R.A.E. Seaplane Tank and Scale Effect Tests on Hulls of Three Sizes. R. & M. No. 1649, British A.R.C., 1935.

Purpose of investigation.- The new tank built at the Royal Aircraft Establishment for seaplane research and development is only 9 feet wide and 4.5 feet deep. These dimensions were chosen as being adequate for tests of models up to 9 feet long. Very little information on tank-wall interference or depth effect is available, and an investigation to determine the limitations of the new tank was therefore undertaken. The work was also extended to determine the scale effect on hulls of three sizes.

Range of investigation.-

(a) Wall interference.- The wall interference on models of length equal to 0.5, 1.0, and 1.5 tank widths was determined by an image method, with the size of model and depth of water kept constant. The tests were carried out on models of a flying-boat hull, and the load on the water was reduced as the speed of test was increased.

(b) Depth effect.- Tests were made in six depths of water corresponding to full-scale depths of 54, 40.5, 27, 13.5, 6.75, and 4 feet for a flying boat approximately 60 feet long. Tests covering the speed range and also representing the application of moments were made; the load on water was adjusted according to the speed and attitude of the hull.

(c) Scale effect.- Three models of a typical seaplane hull were constructed to scales of $\frac{1}{18}$, $\frac{1}{12}$, and $\frac{1}{6}$; and measurements of drag, attitude, and rise were made at all speeds up to the take-off speed. The effect of applied moments was investigated at selected speeds and the spray formation was photographed.

A comparison has been made between the results obtained during these calibration tests and some similar tests made at the Hamburg tank.

Conclusions.-

(a) Wall interference.- The image method used appeared to be quite satisfactory. The effect of the walls on the resistance and running angle was negligible, the only measurable difference occurring in the rise of the model. This difference was small and would not be of any practical importance. It was concluded that the R.A.E. tank was wide enough to test seaplane models up to 9 feet in length without risk of side-wall interference.

(b) Depth effect.- The tests showed that there was a depth effect in shallow water, which was greatest in the neighborhood of the limiting speed of wave propagation corresponding to the depth. At this critical speed the drag, attitude, and rise of the hull all increased as the depth of water was decreased. At high speeds no depth effect was apparent. The results were in good agreement with theory. It was concluded that practically no depth interference would be expected in the R.A.E. tank when testing seaplanes, provided that the model length does not exceed the depth of water available. With models of length equal to twice the depth of water, a small but unimportant depth effect will occur at low speed. As regards the full-scale seaplane, no serious depth effect should be encountered and any effect due to the depth should have a negligible influence on the take-off.

(c) Scale effect.- The magnitude of the scale effect found was small at low and high speeds and reached a maximum at the hump. The results were in accord with the scale effect calculated on the assumption that the flow conditions were fully turbulent.

Insofar as comparisons were possible, it was found that the results obtained in the R.A.E. tank and in the Hamburg tank were generally similar.

RESEARCH
Equipment

389. Truscott, Starr: The Wave Suppressors Used in the N.A.C.A. Tank. NACA TN No. 513, 1934.

So long a time was required for the disturbed water to become quiet after a model had been towed down Langley tank no. 1 that only 12 to 18 runs a day could be made. In order to shorten the time lost in waiting between runs, several different methods of suppressing the waves were tried.

The most effective form of wave suppressor developed consists of wooden frames covered with fine copper screening and secured horizontally just beneath the surface of the water at the sides of the tank. With these suppressors placed every 50 feet along the length of the tank, 40 to 60 test runs a day can be made. [The copper screening was later replaced by wooden slats.]

390. Smith, Leonard: Work in an Experimental Seaplane Tank. Jour. R.A.S., vol. XLVII, no. 393, Sept. 1943, pp. 290-314.

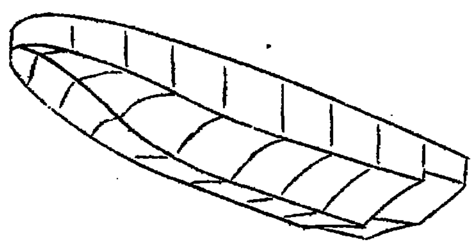
Some of the problems involved in the design of flying-boat hulls are presented and the methods and apparatus for testing models in the Short Brothers tank are described. Some typical results of the tests are given. Emphasis is placed upon the fact that the tank is a source of reliable hydrodynamic design data that cannot be obtained in any other way.

Compromises between good aerodynamic form and good hydrodynamic form are discussed and it is pointed out that changing from the transverse second step to the faired knife-edge second step resulted in a considerable improvement in the aerodynamic "cleanness." It was found that with a well-designed main-step fairing - that is, with the length less than four times the depth of step and with a small break at the end of the forebody - the water performance of a flying boat is satisfactory. Addition of a step fairing to one of the Short flying boats increased the top speed by approximately 5 miles per hour.

In the Short tank the models are towed from a point corresponding to the propeller thrust axis. The resistance is measured by deflecting a torsion rod which scribes a path on a revolving drum. The drum is turned by a drive from the carriage wheels. Rise and trim are indicated by a pointer moving on a calibrated vertical plane.

RESEARCH
Equipment

Some work was done on a model with an inverted-V or sled bow. It was found that although the spray characteristics were good the high air drag and the complications in construction and operation made it impracticable for design considerations.



Sled bow

(See also abstracts 138, 170, 373, 375, and 393.)

Technique

391. Gott, J. P.: Comparison of Results of Tests of the Singapore IIc Model Hull in Five Tanks. R. & M. No. 1785, British A.R.C., 1937.

Tests have been made of the Singapore IIc model hull in five different tanks: N.P.L., Short Brothers, Canadian tank at Ottawa, R.A.E., and NACA. A comparison of these tests is difficult because of the differences in tank technique and because the same model was not used in all the tests. In order to make the comparison more complete, a new series of tests has been made in the R.A.E. tank.

Comparison of the drag measurements in various tanks shows general agreement but the detail differences are considerable. These differences have been attributed to differences in technique, experimental error, and the use of different models. Comparison of the pitching moments measured in three tanks shows systematic differences of the order of 10 to 20 percent. These differences have not been explained. Recent experience suggests that any future comparisons should be made with models 6 or 7 feet long.

392. Locke, F. W. S., Jr.: A Comparison of the Porpoising Characteristics of Duplicate 1/30 Scale Models of the XPB2M-1 Flying Boat. Rep. No. 161-C, Stevens Inst. Tech., Jan. 13, 1942.

Tests of duplicate models of the XPB2M-1 flying boat were made at the Stevens tank to furnish a check on the accuracy of the original model and to permit observation of the effects on porpoising of small changes in test procedure made since the original model had been tested.

The agreement between the tests of the two models under identical test conditions was good. Small differences in the lower trim limits of stability of the two models may be attributed to the interpretation of the original test data. The speed at which the upper limit is first observed and the sustained amplitude of the porpoising cycle may be altered slightly by varying the acceleration of the towing carriage.

393. Stout, Ernest G.: Experimental Determination of Hull Displacement. Aviation, vol. 43, no. 4, April 1944, pp. 121-125, 277, 279, 281, and 283.

A method for the experimental determination of hull displacement and trim is presented. This method is recommended in place of the classical method for determining displacement and trim by use of Bonjean's curves of displacement, which consist of elaborate trial-and-error integrations of the submerged volume and moment of volume. When the classical method is used in seaplane design, much valuable time and money is expended. The equipment and procedures for tests are discussed in detail.

Models are made geometrically similar to the full-size hull and are divided into sections which represent watertight compartments. The models are suspended in a trimming basin by two flexible steel cables that are attached at the chosen centers of gravity. The models are balanced vertically and horizontally about the center of gravity by ballast weights, which bring the center of gravity of the hull to the chosen center of gravity of the complete airplane. The models are counterweighted to provide accurate control of the load on the water. The sections of the hull are supported by a strongback that permits removal of any section or sections and thereby simulates flooded compartments. Trim and rise measurements are taken visually from scales mounted on the supporting cables and on the model. Measurements are usually taken at four centers of gravity over the design range, and plots of trim and draft against center-of-gravity positions are presented. If considerable care is taken in the design and operation of the equipment and models, the accuracy of measurement should be within 1 percent.

394. Stout, Ernest G.: Experimental Determination of Hydrodynamic Stability. Jour. Aero. Sci., vol. 8, no. 2, Dec. 1940, pp. 55-61.

The ability to predict hydrodynamic stability by some simple experimental means, analogous to wind-tunnel testing, is of great importance to the manufacturer of flying boats and seaplanes. Such a method is outlined which involves the testing of a dynamically similar tank model. The characteristics and construction problems of dynamic tank models are considered as well as a general discussion of the testing technique.

While further improvements in methods and equipment are discussed, it is concluded that the present development is adequate for the determination of the range of stability and the proper location for the step. These conclusions are substantiated by the results of full-scale correlation.

395. Gott, J. P.: Interference between Air Flow and Water Flow in Seaplane Tank Testing. TN No. Aero 1460, British R.A.E., July 1944.

In routine water-resistance measurements, corrections are applied for the air forces on the model and measuring apparatus. These corrections are determined by towing the model just above the water surface; the air forces and moments measured are used as tare values. Tank tests have indicated that the forces on a model can be largely affected by air flow around the model and that the usual corrections are inadequate. The evidence is summarized and the possibility of screening models to reduce the air flow past the model is discussed.

The logical procedure in model testing, with present knowledge and equipment, is to determine the stability of a dynamic model first and then to test a screened resistance model.

396. Olson, Roland E., and Land, Norman S.: The Longitudinal Stability of Flying Boats as Determined by Tests of Models in the NACA Tank. I - Methods Used for the Investigation of Longitudinal-Stability Characteristics. NACA ARR, Nov. 1942.

The problem of the longitudinal stability of flying boats while in motion on the water has become of major importance because of the present trends in the design of that type of craft. Mathematical theories for determining the condition of stability of a flying boat while on the water have been suggested but the amount of work involved is extremely large. Until a more simple and accurate method is evolved there will remain a need for tank tests.

Constant-speed runs are made for determining the trim limits of stability. Changes in trim beyond the upper limit, increasing trim, or the lower limit result in porpoising. Accelerated runs are made for determining the stable positions of the center of gravity and for locating the best position of the step.

Small variations (25 percent) in the moment of inertia and in the mass moving vertically have a negligible effect on the trim limits of stability but are more important when determining stable positions of the center of gravity. Increasing the depth of step has little effect on the lower trim limit but increases both of the upper trim limits with an accompanying decrease in the violence of the porpoising. Both upper limits are raised as the load is increased and, with the same available trimming moment, the limits first appear at a higher speed.

RESEARCH
Technique

397. White, H. G., and Smith, A. G.: A Method for Determining the Water Stability of a Seaplane in Take-Off and Landing. Rep. No. H/Res/163, British M.A.E.E., May 22, 1943.

A direct method of determining the water stability in take-off and landing of full-scale seaplanes is described. The customary method of measuring full-scale stability is by steady runs over a range of speeds and attitudes. This method is tedious, does not give the true take-off stability, and does not give the landing stability. The steady-run stability is assumed to correspond very closely to the take-off stability but was originally used to obtain full-scale conditions comparable with model scale. This report gives a method of analysis of take-off records of attitude against speed, and results obtained by this method are compared with the steady-run results.

Results on the Scion and Saro with Shetland hull are used to establish the method, but it has also been checked against the available data on the Seal and Sunderland I.

The take-off stability limits show remarkable agreement with the corresponding steady-run limits $\left(\text{to within } \frac{1}{2}^{\circ}\right)$ of the Scion and Saro. Evidence on the Seal and Sunderland is insufficient for a definite conclusion in these cases, but there is no disagreement between the results obtained. The method is accurate and quick to use but takes no account of the amplitude of porpoising, so that a few steady runs would still be necessary to establish this where required. By use of this method the investigation of the stability characteristics of a seaplane under different conditions of weight, center of gravity, and flap angle can proceed quickly on the evidence of about eight take-off records at each condition, these records covering the full attitude range. The method may also be applied to find landing stability from landing records.

398. Abel, G. C.: Methods of Measuring Speed and Attitude of a Seaplane during Take-Off. Rep. No. F/Res/122, British M.A.E.E., Oct. 17, 1938.

The attitude-speed curve for take-off in the type-trial reports on all new flying boats was required. Various methods of obtaining this curve are discussed. Of the two instruments tested one was a

RESEARCH
Technique

combined accelerometer and pitch recorder, which was readily available, and the other was in the form of a pendulous gyroscope, which was developed. Take-offs were made on several flying boats fitted with both instruments and the results from each instrument are compared.

Good agreement between the records from the two instruments was noted except for a small part at the beginning in which the pendulous gyroscope was less accurate. The combined accelerometer and pitch recorder has proved to be a slightly better instrument than the pendulous gyroscope although both are suitable for determining the attitude-speed curve of a seaplane.

399. Ward, Kenneth E.: A New Method of Studying the Flow of the Water along the Bottom of a Model of a Flying-Boat Hull. NACA TN No. 749, 1940.

A new method of studying the flow of the water along the bottom of a model of a flying-boat hull is described. In this method, the model is fitted with a transparent bottom and divided down the center line by a bulkhead. The flow is observed and photographed through one-half of the model by means of the diffused illumination from a battery of lamps contained in the other half of the model. Photographs of the flow, particularly of the changes that occur when the step ventilates, are shown.

The results of the investigation indicate that the method has considerable promise, chiefly in connection with motion-picture studies.

400. Gott, J. P.: Note on the Technique of Tank Testing Dynamic Models of Flying Boats as Affected by Recent Full Scale Experience. Rep. No. B.A. 1572, British R.A.E., Dec. 1939.

In flight tests of the prototypes Saunders-Roe R1/36 (Lerwick) and Saunders-Roe R2/33, serious porpoising resulted which was not previously reported in model tests. A reevaluation of the tank testing technique for obtaining the upper trim limit of stability showed that the models had not been properly disturbed. The disturbance must be large and of the right kind. A model can be stable to a small disturbance and unstable to a larger one, but even a large disturbance of an unsuitable kind may fail to start the porpoising of an unstable model. The methods of inducing porpoising including disturbances by hand and by waves are included. The use of weight-applied trimming moments on dynamic models is discussed.

Of particular interest is the fact that the dangerous porpoising was eliminated by an increase in gross load of the R2/33 model.

401. Garner, H. M., and Coombes, L. P.: Seaplane Hulls and Floats. Aircraft Engineering, vol. II, no. 18, Aug. 1930, pp. 193-196; and vol. II, no. 19, Sept. 1930, pp. 223-225.

Methods and assumptions leading to the use of Froude's law of comparison in seaplane model testing are reviewed. Full-scale and model seaplane-testing techniques are discussed and the results are analyzed.

The procedures used in extrapolating resistances of ship models to full size are discussed and an attempt is made to find some similar method for use on seaplane models.

Several methods of determining the resistance R of a full-scale seaplane are:

(1) A seaplane may be towed through the water by a high-speed boat (such as a torpedo destroyer) on a long tow and the load in the tow rope measured.

(2) Resistance can be determined indirectly by measuring the forward acceleration $a$, measuring or estimating the airscrew thrust $T$, and estimating the air drag $D$, and by substituting these values into $T - R - D = Ma$, where $M$ is the mass of the seaplane.

(3) Direct measurements of resistance can be made by measuring the forces existing between the float and the fuselage of a single-float seaplane while the seaplane is taxying at a constant speed.

Approximately the same take-off times are obtained if T/W, the ratio of thrust to the weight, is unaltered. Take-off tests at full load, which are very difficult to carry out under certain conditions, can therefore be replaced to a first approximation by throttled tests at the normal load.

RESEARCH
Technique

In the second part of the article methods of attacking various problems relating to seaplane research are presented and the data available are briefly summarized. A discussion of longitudinal and lateral stability is presented with an analysis of stub-wing and wing-float stabilizers. Various methods of measuring hull-bottom pressures are cited.

(See also abstracts 47, 249, 256, 273, 277, 283, 305, 373, 375, 379, 380, 387, and 390.)

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

ESY

# AUTHOR INDEX

## AUTHOR INDEX

(Numbers refer to abstracts.)

[redacted]

SUBJECT INDEX

SUBJECT INDEX

[redacted]

SUBJECT INDEX

(Numbers refer to abstracts. The letter X (experimental) and model number have been deleted from Naval seaplane designations.)

[redacted]

Water rudder: 14

Wing loading: See Hull loading.

Wing setting: 43, 49

NASA Technical Library
3 1176 01436 2744